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PROPOSED PAYLOAD FOR ATM-B FOR OBSERVING HIGH-ENERGY CELESTIAL SOURCES

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PROPOSED PAYLOAD FOR ATM-B FOR OBSERVING HIGH-ENERGY CELESTIAL SOURCES

By Advanced Systems and Technologies Group
Brown Engineering Company, Inc.

ABSTRACT

This study describes a realistic and practical candidate payload for ATM-B. The eight electromagnetic radiation experiments considered in this study were specified by the Office of Space Science and Applications, NASA Headquarters.

ATM-A systems and Saturn hardware were utilized wherever possible.

In addition to defining subsystem requirements for this package emphasis has been placed upon mission analysis and experiment scheduling for a 56-day low-altitude mission.

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LIST OF ABBREVIATIONS

AAP	Apollo Application Program
ACE-S/C	Acceptance Checkout Equipment Spacecraft
ADC	Analog Digital Converter
ADU	Astronaut Display Unit
AGCS	Automatic Ground Checkout System
AM	Airlock Module
AMO	Air Mass Zero
AOT	Alignment Optical Telescope
APIC	Apollo Parts Information Center
ASAP	Auxiliary Storage and Playback
ATM	Apollo Telescope Mount
BeV	Billion Electron Volt
CCS	Command and Communication System
CG	Center of Gravity
CM	Command Module
CMG	Control Moment Gyro
c/o	Checkout
CRT	Cathode Ray Tube
CSM	Command Service Module
DDAS	Digital Data Acquisition System
DEDA	Data Entry and Assembly
DPS	Design and Performance Specifications
DTR	Digital Tape Recorder
ECS	Environmental Control System
ECE	Experiment Checkout Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMR	Electromagnetic Radiation
EMU	Extravehicular Mobility Unit
EPCS	Experiment Pointing Control Subsystem
ESE	Electrical Support Equipment
EVA	Extravehicular Activity
FM	Frequency Modulated
FMECA	Failure Mode, Effect, and Criticality Analysis
GETS	Ground Equipment Test Set
GNCS	Guidance, Navigation, and Control Subsystem
GOX	Gaseous Oxygen
GSE	Ground Support Equipment
I&CS	Instrumentation and Communication System

LIST OF ABBREVIATIONS - Concluded

IDEP	Interservice Data Exchange Program
IU	Instrument Unit
KSC	Kennedy Space Center
LAOT	Large Aperture Optical Telescope
LCC	Launch Control Center
LM	Lunar Module (Ascent Stage Only)
MDA	Multiple Docking Adapter
MeV	Million Electron Volts
MMF	Memory Module and Formating Unit
MMI	Mass Moment of Inertia
MSC	Manned Spaceflight Center
MSE	Mechanical Support Equipment
MSFC	George C. Marshall Space Flight Center
MSFN	Manned Spaceflight Network
MTBF	Mean Time Between Failure
MUX	Multiplex
ORNL	Oak Ridge National Laboratories
OSSA	Office of Space Science Application
OWS	Orbital Workshop
PAM	Pulse Amplitude Modulation
PCM	Pulse Code Modulator
PCS	Pointing Control Subsystem
PDP	Program Development Plan
PHA	Pulse Height Analyzer
PI	Principal Investigator (Experimenter)
PLSS	Portable Life Support System
PM	Photomultiplier
PRINCE	Parts Reliability Information Center
RACS	Remote Automatic Checkout System
RCS	Reaction Control System
RF	Radio Frequency
RFI	Radio Frequency Interference
SDBF	System Development Breadboard Facility
SLA	Spacecraft LM Adapter
SPS	Service Propulsion System

FOREWORD

Many of the details included in this report were supplied by the George C. Marshall Space Flight Center, Naval Research Laboratory, University of California, American Science and Engineering, Inc., Goddard Space Flight Center, University of Arizona, Princeton University, Case Institute of Technology, and Office of Space Science and Application, NASA Headquarters, Washington, D. C.

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PROPOSED PAYLOAD FOR ATM-B FOR OBSERVING HIGH-ENERGY CELESTIAL SOURCES

SUMMARY

This study includes a system definition and feasibility analysis of a practical and realistic celestial observatory candidate payload for the ATM-B flight. The eight electromagnetic radiation experiments considered in this study were specified as a result of previous OSSA directed study activity. This grouping of experiments was selected because of nonduplicating scientific objectives and because their stage of development would appear to permit an early flight. ATM-A Baseline systems and Saturn hardware were utilized wherever possible.

The basic concept shows all experiments mounted on three separate platforms (ultraviolet, gamma-ray, and X-ray) rather than mounted to either the gimbal system or canister. Each platform is mounted on a boom which is fixed to the ATM-A rack. Each experiment, by means of deployment and scanning mechanisms on each boom, is provided with a hemisphere or more of observation. Each platform may be oriented independent of the others as well as of the cluster. Two of these platforms will be simple remote control mechanisms to change the viewing angle of the gamma-ray and X-ray experiments. The third unit will be an inertial platform to provide the accuracy and stability required by the ultraviolet experiments. This permits autonomous operation of the experiments on each boom and observation of three different sources simultaneously. Thus a more economical usage of mission time is possible and RCS fuel for cluster reorientation is minimized.

Since the experiments are mounted on remote separate platforms rather than inside the rack and since these are not solar viewing instruments with extremely narrow temperature limitations, the thermal problems will be less severe than on ATM-A. Also since a 2.5-arc second optical bench is not required, misalignment problems due to thermal gradient will not occur.

All experiments can easily be scheduled within the 56-day mission and a shorter mission will still provide considerable scientific rewards.

Attitude control of the entire cluster will be accomplished by using the same control moment gyro (CMG) system used on the ATM-A baseline system.

The total payload weight for this candidate ATM-B payload is very close to that currently estimated for ATM-A and well within the payload capabilities of the S-IB/S-IVB booster.

The power requirements for this payload can adequately be met by using 16 of the present ATM-A solar panels.

The instrumentation and communications subsystem requires a minor change to the ATM-A configuration. Another auxiliary storage and playback unit and transmitter are added to satisfy the higher data recording rate for this payload.

Present development of various elements of this candidate for ATM-B appear compatible with the current program schedule.

SECTION I. INTRODUCTION

The scientific community, through its official channels of input to the space program such as the published National Academy of Sciences Reports, the Presidential Scientific Advisory Committee, the Ramsey Committee, and other advisory groups to National Aeronautics and Space Administration (NASA), has recommended that strong emphasis in future space astronomy missions be given to the areas of ultraviolet, X-ray, and gamma-ray astronomy. In line with these recommendations eight electromagnetic radiation celestial experiments have been proposed as a candidate payload for the ATM-B flight. These eight experiments were selected for this study from OSSA candidate lists, and the combination appears feasible and has nonduplicating scientific objectives.

The proposed payload is an appropriate one for an early Apollo Applications Program (AAP) mission because of its relatively low cost and flexibility. The University of Arizona is designing the ultraviolet photography survey cameras. The Naval Research Laboratory is responsible for the design of the X-ray sky survey panels and the far ultraviolet spectrograph. American Science and Engineering, Inc., is supplying the modulated collimator X-ray detector. Goddard Space Flight Center is supplying the digitized spark chamber and low energy gamma-ray sky survey spectrometer. The University of California is supplying the design for the gamma-ray and X-ray spectrometers. Princeton University is designing the far ultraviolet spectrograph. Case Institute of Technology supplied the design of the spark chamber for solar and cosmic gamma rays. ATM-A systems were used in this study wherever practicable.

Since the ATM-A Baseline and experiments are under continued development and change, it was necessary to establish a cutoff date of December 15, 1967, for this study (Ref. 1 and 2).

A. Guidelines

The guidelines used for this report are as follows:

- The orbital workshop cluster mission concept was considered to be the prime mode of operation.

- Solar vector orientation was maintained for the cluster throughout the orbit to minimize RCS propellant requirements.

- ATM-A systems and Saturn hardware were used wherever practicable.
- ATM-B is docked at 90 degrees to the CSM in the basic cluster configuration.
- No resupply provision was considered. Adequate supplies for the entire mission are included in the original payload.
- The cluster is in a 230-nautical-mile-circular orbit for 56 days.
- All experiments were assumed to have the same priority or "utility value".
- Experiment summaries used in this study were to include only engineering interface information for systems integration.

B. Scope

A payload for observing high-energy celestial sources is proposed as a candidate package for the ATM-B. It is an outgrowth of ATM follow-on study efforts by Marshall Space Flight Center. The mission includes the following experiments:

Experiment	Principal Investigator	Sponsor
Ultraviolet Photographic Survey	Tifft	University of Arizona
Far Ultraviolet Spectrograph	Carruthers	Naval Research Laboratory
Modulated Collimator X-ray	Gursky	American Science and Engineering
Low-energy Gamma-ray Sky Survey	Frost	Goddard Space Flight Center
Spark Chamber or Digitized Spark Chamber	Frye or Fichtel	Case Institute or Goddard Space Flight Center

Gamma-ray and X-ray Spectroscopy	Peterson	University of California
X-ray Sky Survey Panels	Friedman	Naval Research Laboratory
Far Ultraviolet Spectrograph	Morton	Princeton University

The Carruthers, Friedman, and Fichtel experiments are included in this payload but were not listed in the original six priority 1 experiments as described by OSSA. Carruthers' spectrograph was included since a preliminary design analysis had been completed by MSFC of an ultraviolet stabilized platform which successfully incorporated it with Dr. Tifft's ultraviolet cameras and Morton's ultraviolet spectrograph. The Frye spark chamber was used in these configuration layouts; however, the Fichtel digitized spark chamber can be used as an alternate. Either spark chamber is compatible with this payload. The Friedman experiment was included to perform an X-ray sky survey and to utilize the balance of the weight-carrying capability of the launch vehicle.

C. Scientific Objectives

1. <u>Gamma Radiation.</u> Extraterrestrial gamma rays usually occur as a result of any of the following mechanisms:

- Decay of neutral pions produced by cosmic rays in the interstellar medium
- Bremsstrahlung of relativistic electrons and positrons
- Compton scattering of relativistic electrons by thermal photons (inverse Compton effect)
- Positron annihilation
- Nuclear interactions and decays.

Gamma rays can thus originate from a "point" object ot an extended one. Some of the mechanisms listed above produce gamma rays at specific energy levels, others produce a continuum of energies.

The detection of gamma rays can provide new information about fundamental high energy processes within and external to our galaxy. Presently, little is known about the spectrum and direction of the gamma rays and line spectra from celestial sources have not been observed.

A variety of instruments exist that will in combination detect radiation from the lowest energies associated with gamma rays up to the BeV range. The intention is to search for, to map gamma-ray sources, and to find their spectrum and flux density. In addition more will become known about the isotropic component and a possible extended source along the galactic plane.

2. X-Radiation. More than 25 discrete sources have been detected. Because the sensitivity of one of the X-ray detectors is one or two orders of magnitude greater than those used on previous flights, sky mapping is expected to reveal a large number of previously undetected sources. Several mechanisms may contribute to the observed X-ray intensity. Neutron stars have been proposed as possible sources of thermal X-radiation from the Crab nebula and Scorpius. High-energy electrons gyrating about magnetic field lines of a supernova may emit synchrotron radiation; high-energy electrons may give off bremsstrahlung radiation when scattered from protons or other nuclei; cosmic electrons may interact with bound electrons of heavy atoms to generate characteristic X-rays; or cosmic ray electrons may interact with stellar photons to increase their energy to the X-ray range.

Measurements will be taken to establish spectral and photometric values which should offer an improvement over previous data. The angular resolution which will be attained will provide more accurate information on the position and angular dimension of sources which are associated with different X-ray energies. Also, the measurement of the isotropic background intensity and spectral distribution will be provided.

It is expected that X-ray astronomy will make important contributions to an understanding of high-energy cosmic processes, the generation of fast electrons and possibly cosmic rays, the composition and density of gaseous matter between stars and galaxies, and possibly the nature of highly condensed matter states, such as the hypothetical neutron star.

3. Ultraviolet Radiation. The near-ultraviolet cameras and the far-ultraviolet spectrographs will obtain medium to high resolution data on stars, the interstellar medium, and extragalactic objects by means of wide-angle sky surveys. Specific spectral areas and line emissions will be studied, and photometry data and mapping information will be obtained.

All three instruments require the cluster pointing accuracy and improved attitude control capabilities and must be above most of the Earth's atmosphere to eliminate disturbances and background.

A program of study using the proposed ultraviolet instruments could span several years. The experiment would conduct an ultraviolet sky survey, using a combination of a medium to high resolution imaging system and image converter spectrographs. Extending the observable frequency range beyond atmospheric cutoff will permit a coordinated study of stellar objects such as hot stars which emit primarily in the ultraviolet. Also, much more information may be gained about objects displaying ultraviolet excesses such as quasars.

D. Mission Description

The objective of this mission is to conduct scientific exploration into the regions of stellar astronomy that have only been touched upon by rocket, balloon, and small satellite flights. This mission is significantly enhanced by the capabilities of the Saturn/Apollo systems. The launch sequence involves the launch from Kennedy Space Center (KSC) of the uprated Saturn I vehicle carrying the ATM-B payload at a time and azimuth to enable the launch vehicle to rendezvous with the orbiting cluster.

E. System Description

The system consists of three basic groups of components: the operational instruments, the supporting secondary structure, and the electrical and electronic equipment both peculiar to one experiment or common to two or more scientific instruments.

The instruments and their external equipment will be mounted on an equipment rack, which will be mounted to the Lunar Module (LM)/ Ascent Stage. The rack structure is based on the LM/Descent Stage frame structure, but without landing legs or rocket engine.

F. Experiment Equipment Description

There are eight different experiment packages that comprise the proposed ATM-B payload. Each package is sensitive to different energy levels but there is some overlapping of levels between experiments. The combination of experiments can record data from as low as 4 eV in the near-ultraviolet region up the BeV range in the gamma-ray region. These experiments utilize instruments which are appropriate for a sky survey type mission and, consequently, should be flown early in the AAP.

All the gamma-ray detectors are mounted on a single platform and aligned to view in the same direction. They include a high-energy spark chamber and two all-crystal spectrometers. The all-crystal detector instruments are sodium iodide (medium-energy gamma-ray spectrometer) and cesium iodide (low-energy gamma-ray sky survey spectrometer); and both have an active anticoincidence collimation shield of cesium iodide. In addition, a spectrometer sensitive to energy in the X-ray band will be paired with the medium energy spectrometer and located next to it. All data are to be recorded and telemetered back to Earth.

The two X-ray experiments are basically proportional counters. They have passive shield collimators which allow for greater sensitivity. The modulated collimator X-ray detector has a very fine slit and grid collimation system which allows for very fine angular resolution. Both experiments operate by scanning past the source. They are mounted on the X-ray panel wings.

The ultraviolet spectrum will be observed by two far-ultraviolet spectrographs with objective gratings and two near-ultraviolet cameras. One spectrograph is of the Schmidt type and the other is an all-reflective type. Incident ultraviolet radiation causes the emission of electrons from a photocathode within the Schmidt spectrograph. These electrons are focused onto a nuclear track emulsion film. The all reflecting spectrographic uses direct recording of the spectra on film. The near ultraviolet cameras employ filters and then focus light onto ultraviolet sensitive film. The cameras are identical except for the filtering arrangement.

All ultraviolet detection apparatus will be mounted on an instrumentation platform. The platform will allow the apparatus to view a source for the duration of an exposure series.

SECTION II. JUSTIFICATION

The proposed ATM-B system concept accommodates a complement of astronomical experiments in which radiation in the ultraviolet, X-ray, and gamma-ray regions of the electromagnetic spectrum is detected. Sky mapping as well as detailed studies of selected sources and a search for new ones will be conducted.

The ATM-B incorporates existing technologies and scientific capabilities. Maximum use can be made of shelf items and no major production problems are foreseen. These factors together with the utilization of the MSFC fabrication capabilities help to contribute to the fact that the total cost of the ATM-B is relatively modest.

The experiments have the backing of prominent members of the scientific community, and the intentions are coincident with the mainstream of scientific opinion, such as those expressed by the National Academy of Sciences concerning the use of Earth-orbital Astronomy Laboratories. The launch and intended orbit are within the capabilities of the Apollo system.

Astronomical observations above the atmosphere provide the distinct advantages over conventional study because the turbulence and opacity of the Earth's atmosphere has restricted Earth-bound observations to less than optimum resolution and to certain wavelengths of the electromagnetic spectrum.

A manned ATM-B offers several advantages that cannot be matched by an unmanned spacecraft. A few of the ATM-B activities that have been designated to be performed by the astronauts are as follows:

- Recover film from some of the experimental apparatus
- Perform periodic checks to insure that instruments are correctly aligned
- Determine some exposure times
- Make on-the-spot changes in experimental procedure as the situation demands

- Make adjustments and minor repairs on equipment as required
- Reorient the spacecraft or instrument platform to observe another target.

Discrete sources have not been detected at many energy levels within the gamma-ray range. No anisotropy has been found, for example, at nuclear-decay energy ranges, although the existence of sources for this range is assured by theoretical arguments. The lack of observations has been due to the very low flux that must be reaching Earth from these sources and the high background. By rising above the atmosphere and building good directional capabilities into the equipment, sources should now be detectable because of the Apollo systems capabilities in attitude control for long periods of time. The instruments should be capable of measuring flux density, direction dependence, and spectrum. The gamma-ray detectors can view known X-ray sources, and the shape of the X-ray continuum for energies greater than 50 keV may be studied.

There are many extremely powerful celestial energy sources that produce energy by mechanisms that are not understood. Gamma radiations are capable of penetrating through interstellar and intergalactic space in a straight line with essentially no attenuation. A gamma ray with an energy of only a few MeV, for example, can traverse distances as great as the Hubble distance (1.3×10^{28} cm). Consequently, it is expected that gamma-ray spectrometry may become a most important tool for astrophysical studies as techniques are developed. It is conceivable that the lessons learned in these first experiments may establish basic guidelines for future experimenters.

Sky mapping in the X-ray range is expected to reveal a large number of previously undetected sources. Sensitivity will be one to two orders of magnitude better than the equipment that has been flown in rockets. The fine collimation system that is present will allow more accurate mapping and dimensioning to be accomplished than ever before. However, to achieve greater sensitivity, a larger viewing area is necessary, and thus a heavy payload. When the necessity of viewing from above the atmosphere is also considered, then use of a system such as is available with AAP is essential. The X-ray apparatus may be expected to locate new sources and obtain better spectral data of known sources at different energy levels.

Ultraviolet radiation emitted by celestial objects will provide much needed information to aid in the understanding of stellar and galactic phenomena. Comparison of a large number of stars of the same spectral types, but at varying distances, should enable determination of the composition, density, and distribution of the interstellar medium. Mapping, photometry, and spectral measurements are the general objectives.

SECTION III. MISSION ANALYSIS

A. Mission Profile

The ATM-B mission will begin with the launch of a CSM containing a three-man crew into a low parking orbit. A second unmanned launch on the following day will place the LM/ATM-B into a low parking orbit. The CSM will then rendezvous with the LM/ATM and transport it to and dock with an orbiting cluster configuration in a circular 230-nautical-mile, 28.5-degree inclination orbit. The cluster will consist of an OWS, an MDA, and an AM. After checking out all systems and equipment, the crew will proceed to conduct a series of observations of gamma-ray, X-ray, and ultraviolet emissions of celestial sources and sky surveys in the gamma- and X-ray spectral regions. The crew will return to Earth at the end of 56 days.

An example of an overall mission timeline which might be followed is given below:

Day 1:	Launch of the CSM and three-man crew.
Day 2:	Unmanned launch of the LM ascent stage and ATM-B equipment. Rendezvous and docking of the LM/ATM-B with the CSM and subsequent rendezvous and docking of LM/ATM-B and CSM with orbiting cluster.
Days 3-7:	Checkout of the LM/ATM-B systems and equipment. Preparation for extended stay in orbit and conduct of experiments.
Days 8-11:	Performance of ATM-B experiments.
Day 12:	EVA and ATM-B experiments.
Day 13:	Rest.
Days 14-17:	ATM-B experiments.

Day 18: EVA and ATM-B experiments.

Day 19: Rest.

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Days 44-47: ATM-B experiments.

Day 48: EVA and ATM-B experiments.

Day 49: Rest.

Day 50-53: ATM-B experiments.

Day 54: EVA and preparation for retrofire.

Day 55: Continue preparation for retrofire.

Day 56: Separate CSM from cluster, conduct deboost, entry and recovery operations.

EVA is scheduled every fifth day to recover exposed film and to permit an external examination of the equipment; a day of rest is scheduled following each EVA day.

The astronaut schedules illustrated in Figure 1 are considered to be representative of those which might be followed on this mission during days of ATM-B experiment operations and EVA. The Experiment Day Schedule provides for two men being in the LM available to conduct experiments for 11 hours and for one man in the LM available to conduct experiments for eight hours each day. It is assumed that the LM can accommodate two experimenters simultaneously, but not three. The EVA Day Schedule provides for all three crew members being awake during the two-hour preparation period, the three-hour (maximum) EVA period, and the one-hour post EVA period. During the actual EVA, one astronaut would be suited up and prepared for EVA to assist the outside astronaut and the other would be monitoring the spacecraft systems. On EVA days, two men are available to conduct experiments for five hours and one man is available for six hours. Thus there are 30 manhours available for experiments on experiment days and 16 manhours available for experiments on EVA days. No manhours are available for experiments during rest or special activity days.

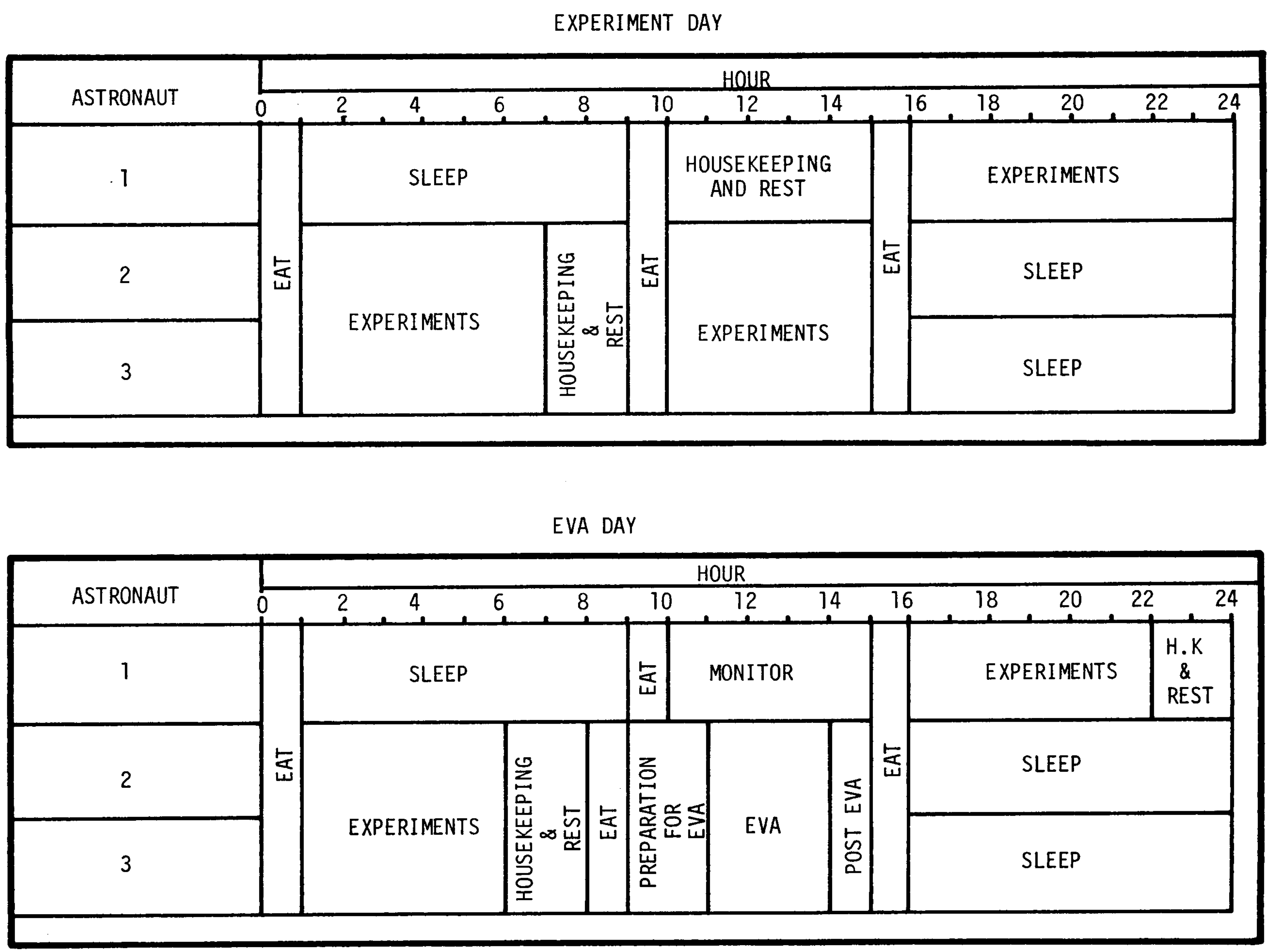


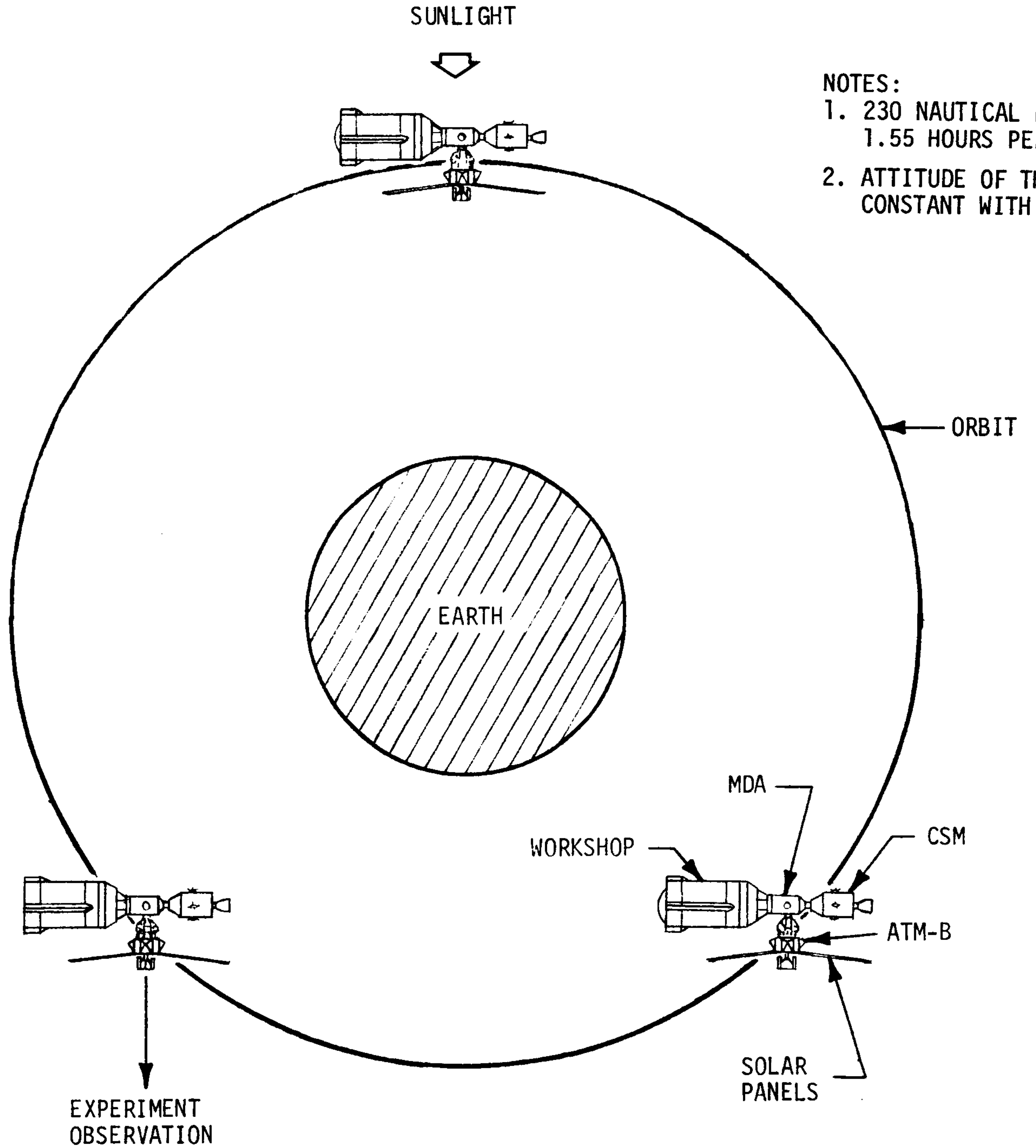
FIGURE 1. ASTRONAUT DAILY SCHEDULES FOR EXPERIMENT AND EVA DAYS

After the CMGs are running at the proper speed, they will be used to maintain the desired orientation of the cluster during the remainder of the mission. The orientation of the cluster with respect to the Sun and its attitude with respect to the Earth are shown in Figure 2. It is necessary to maintain the plane of the solar panels approximately perpendicular to the solar vector in order to generate the required electrical power. This orientation is not required during the dark portion of the orbit, but if a different orientation in darkness were permitted, a cluster reorientation would be required on each orbit as the cluster entered the sunlight.

The period of the orbit is approximately 93 minutes. When the plane of the orbit is in line with the Sun (edge-on) the duration of the sunlight portion of the orbit will be approximately 57 minutes and the duration of the dark portion of the orbit will be approximately 36 minutes. When the plane of the orbit is inclined at some angle to the Sun, as it will be most of the time, the duration of the sunlight portion of the orbit will be longer than 57 minutes. The orientation of the orbit plane with respect to the Sun will change during the mission due to precession of the orbit and to the change in the declination of the Sun. The rate of orbital precession was calculated (Ref. 3) to be 6.9 degrees per day; therefore, the orbit will precess through slightly more than one complete revolution during the mission.

B. Experiment Requirements

Two types of experiments will be conducted during the ATM-B mission -- viewing of point sources and scanning of the celestial sphere. It is desirable to scan as large a portion of the celestial sphere as possible, and for this reason all instruments will remain turned on throughout the mission. Table 1 gives a listing of X-ray, gamma-ray, and UV point sources which are considered to be typical of those of interest. Table 1 also includes the desired viewing time and the location of each source as measured in hours and minutes of right ascension from the vernal equinox and the declination in degrees measured from the celestial equator. These point sources are plotted on a chart of the celestial sphere in Figure 3. The straight horizontal line passing through the middle of the chart is the ecliptic or the path of the Sun through the sky. The curved horizontal lines are lines of constant declination, and the vertical curved lines are lines of constant right ascension.



NOTES:
1. 230 NAUTICAL MILE CIRCULAR ORBIT. 1.55 HOURS PER ORBIT
2. ATTITUDE OF THE CLUSTER REMAINS CONSTANT WITH RESPECT TO THE SUN.

FIGURE 2. CLUSTER ORIENTATION

TABLE 1. EXAMPLES OF TYPICAL CELESTIAL SOURCES OF INTEREST ON THE ATM-B MISSION

Source No.	Gamma-ray Sources	Right Ascension (hr)	(min)	Declination (deg)	(min)	Desired Viewing Time (hr)
1	Crab Nebula	5	32	+22	00	10.00
2	Galactic Center	17	43	-28	00	8.33
3	Andromeda (M31)	0	40	+41	00	10.00
4	Virgo A (M87)	12	29	+12	37	10.00
5	Centaurus	13	23	-42	49	8.33
6	Hercules A	16	49	+05	5	8.33
7	Cygnus A	19	58	+40	37	10.00
8	Cassiopeia A	23	22	+58	35	8.33
9	Cassiopeia B	0	22	+63	52	8.33
10	Scorpius	16	15	-15	00	10.00
11	Small Magellanic Cloud	0	51	-73	6	8.33
12	Large Magellanic Cloud	5	24	-69	48	8.33
	X-ray Sources					
13	Cyg XR-1	19	3	+34	36	0.33
14	Cyg XR-2	21	43	+38	48	0.37
15	Cyg XR-3 (Cyg A)	19	58	+40	30	0.43
16	Cyg Loop (2 sources)	20	48	+30	48	0.43
17	Cyg XR-4	21	21	+44	00	0.40
18	Crab Nebula	5	32	+22	00	0.33
19	Sco XR-1	16	7	-15	31	0.33
20	Sco XR-2	17	8	-36	24	0.33
21	Sco XR-3	17	23	-44	18	0.33
22	Oph XR-1	17	32	-20	42	0.33
23	Sgr XR-1	17	55	-29	12	0.33
24	Sgr XR-2	18	10	-17	6	0.33
25	Ser XR-1	18	45	+ 5	18	0.42
26	M87 (Virgo)	12	28	+12	42	0.50
27	Cas A	23	21	+58	33	0.48
28	Leo XR-1	9	35	+ 9	00	0.50
	Ultraviolet Sources*					
29	γ Cas	0	58	60	30	0.33
30	h, χ Pers	2	14	57	00	0.33
31	ϵ, ξ Pers	3	56	39	00	0.33
32	ζ Pers	3	54	33	30	0.33
33	Pleiades	3	44	24	00	0.33
34	Crab Nebula (M1)	5	30	22	00	0.33
35	λ Ori	5	36	9	54	0.33

TABLE 1.- Concluded

Source No.	Ultraviolet Sources*	Right Ascension (hr)	(min)	Declination (deg)	(min)	Desired Viewing Time (hr)
36	δ, ε, ζ, σ, η Ori	5	36	- 1	12	0.33
37	θ_1, θ_2, i Ori and M42	5	34	- 5	24	0.33
38	β Ori, λ Eri and λ Lep	5	7	-10	0	0.33
39	NGC 2244	6	30	5	0	0.33
40	S Mon, NGC 2264	6	22	10	0	0.33
41	HD 54662, NGC 2353 and NGC 2335	7	7	-10	18	0.33
42	α C Ma	6	40	-16	36	0.33
43	β C Ma	6	20	-18	0	0.33
44	ε, κ C Ma	6	52	-30	30	0.33
45	τ, uω, ω C Ma	7	17	-24	54	0.33
46	ζ Pup	8	0	-39	54	0.33
47	γ Vel	8	8	-47	12	0.33
48	f Vel	8	49	-46	18	0.33
49	η Car	10	43	-59	24	0.33
50	θ Car	10	41	-64	6	0.33
51	α Cru	12	23	-62	48	0.33
52	β Cru	12	45	-59	24	0.33
53	β Cen	14	1	-60	6	0.33
54	δ Cir	15	14	-60	48	0.33
55	ζ, μ, χ Cen	14	4	-44	0	0.33
56	α Lup	14	38	-47	12	0.33
57	β Lup, κ Cen	14	56	-42	0	0.33
58	γ, η Lup	15	50	-39	30	0.33
59	Hd 150136	16	38	-48	42	0.33
60	ζ' Sco, NGC 6231	16	53	-42	18	0.33
61	λ, κ Sco	17	34	-38	0	0.33
62	$\mu^{1,2}$ Sco	16	49	-37	54	0.33
63	$\alpha^{1,2}$, τ, σ Sco	16	26	-26	18	0.33
64	β, δ, π Sco	15	57	-22	30	0.33
65	HD, 155806, M6	17	12	-33	30	0.33
66	HD, 159176	17	32	-32	36	0.33
67	HD, 164794, M8	18	1	-24	24	0.33
68	M 20	17	59	-23	0	0.33
69	M 16	18	16	-13	48	0.33
70	ρ Cyg	20	16	37	54	0.33
71	HD 199567, NGC 7000	20	55	44	42	0.33
72	HD 206267	21	37	57	18	0.33
73	γ Cep	22	10	59	12	0.33
74	β Cep	14	48	70	18	0.33
75	10 Lac	22	37	38	48	0.33
76	α Cam	4	49	66	18	0.33
77	α, ρ Lco	10	18	10	42	0.33
78	S, 30 Dor, and LMC	5	40	-69	0	0.33

*When more than one source is listed, the coordinates refer to a point on the celestial sphere to which the ultraviolet equipment should be pointed. The finite field of view of the apparatus will then simultaneously look at all listed sources.

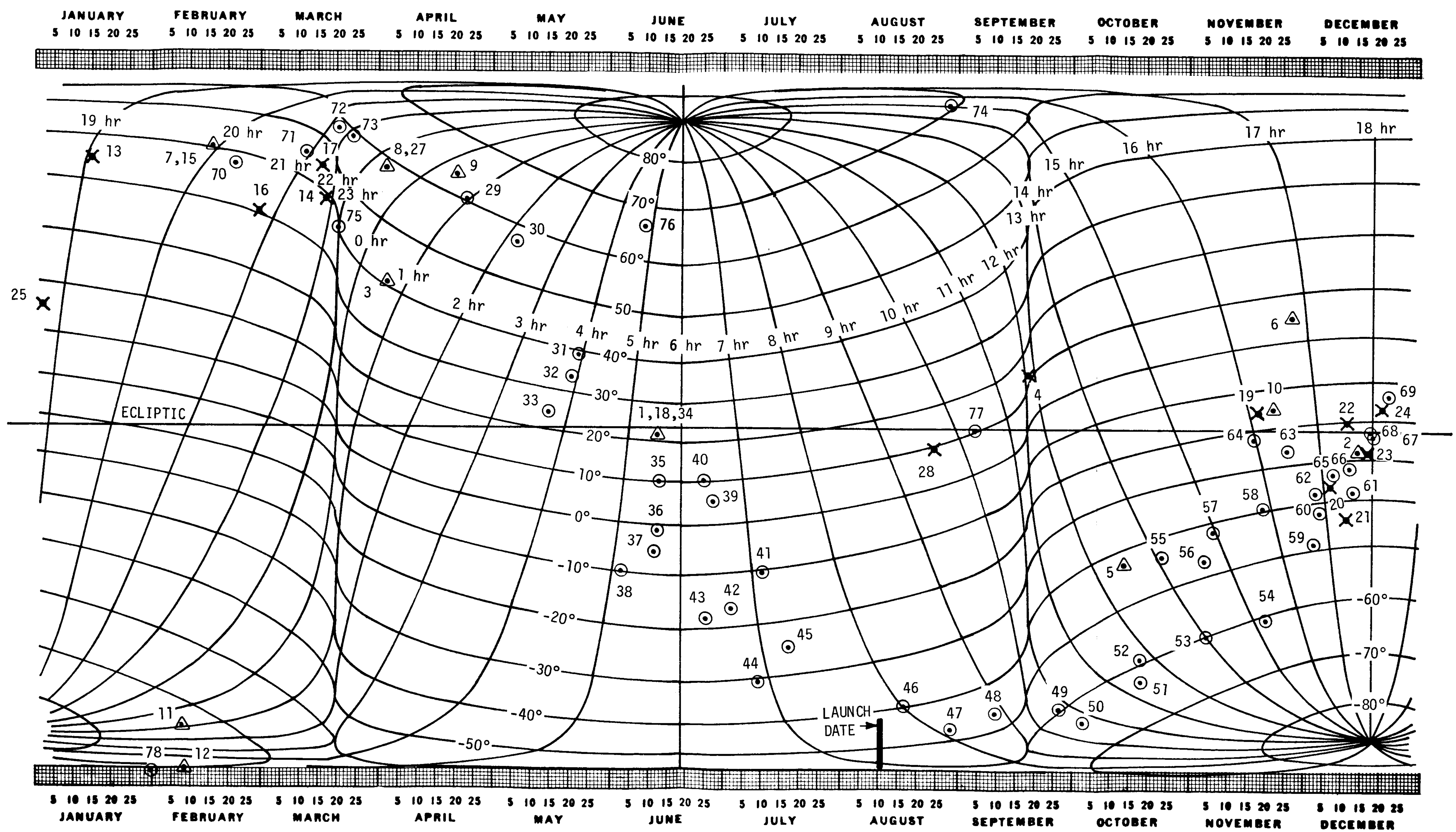


FIGURE 3. LOCATION OF GAMMA-RAY, X-RAY, AND ULTRAVIOLET SOURCES ON THE CELESTIAL SPHERE

GAMMA RAY
X-RAY
ULTRAVIOLET

The location of the Sun will obscure some sources for all or portions of the mission. Due to interference from solar emissions, gamma-ray sources which are within 10 degrees of the Sun and ultraviolet sources which are within 30 degrees of the Sun cannot be observed on this mission. Due to the design of the deployment mechanism for the X-ray experiment equipment on this flight and to the constraint on alignment of the solar panels perpendicular to the solar vector at all times, X-ray sources which are within 90 degrees of the Sun cannot be observed.

C. Selection of Launch Date

The areas of the celestial sphere in which viewing by each type of instrument is obscured by the Sun will change each day as the position of the Sun against the star background changes. These areas are apparent circular areas on the celestial sphere centered on the Sun. They have different angular radii for the ultraviolet, gamma-ray and X-ray instruments. Because of the apparent motion of the Sun among the stars, there will be portions of the sky in which sources will be visible during part, but not all, of the mission. For large limiting angles, certain areas will be entirely obscured throughout a mission.

An overlay placed on Figure 3 may be used to determine the areas of partial and total obscuration as a function of mission launch date. Because of the yearly motion of the Earth about the Sun, the Sun undergoes an apparent eastward motion among the stars along a path known as the ecliptic. The ecliptic plane is tilted at an angle of 23.5 degrees to the Earth's equatorial plane. Because it is desired to determine the area of the sky that is obscured as a function of time (the launch date), a sky plot and overlay were chosen as the only way of conveniently demonstrating this. Figure 4 illustrates the placement of a gamma-ray overlay on the sky plot. The shaded area represents the area of the celestial sphere which is within 10 degrees of the Sun during a portion of the 56-day mission beginning on the indicated launch date. No gamma-ray sources are obscured during the entire mission. Figure 5 illustrates the placement of an ultraviolet source overlay on a chart of sources. The shaded area represents the area of the celestial sphere which is within 30 degrees of the Sun during a portion of the mission. For most launch dates, no ultraviolet sources will be obscured during the entire mission. Figure 6 illustrates the placement of an X-ray source overlay on a chart of sources. Due to the much larger area obscured to X-ray instrument viewing, some sources will be obscured during the entire mission.

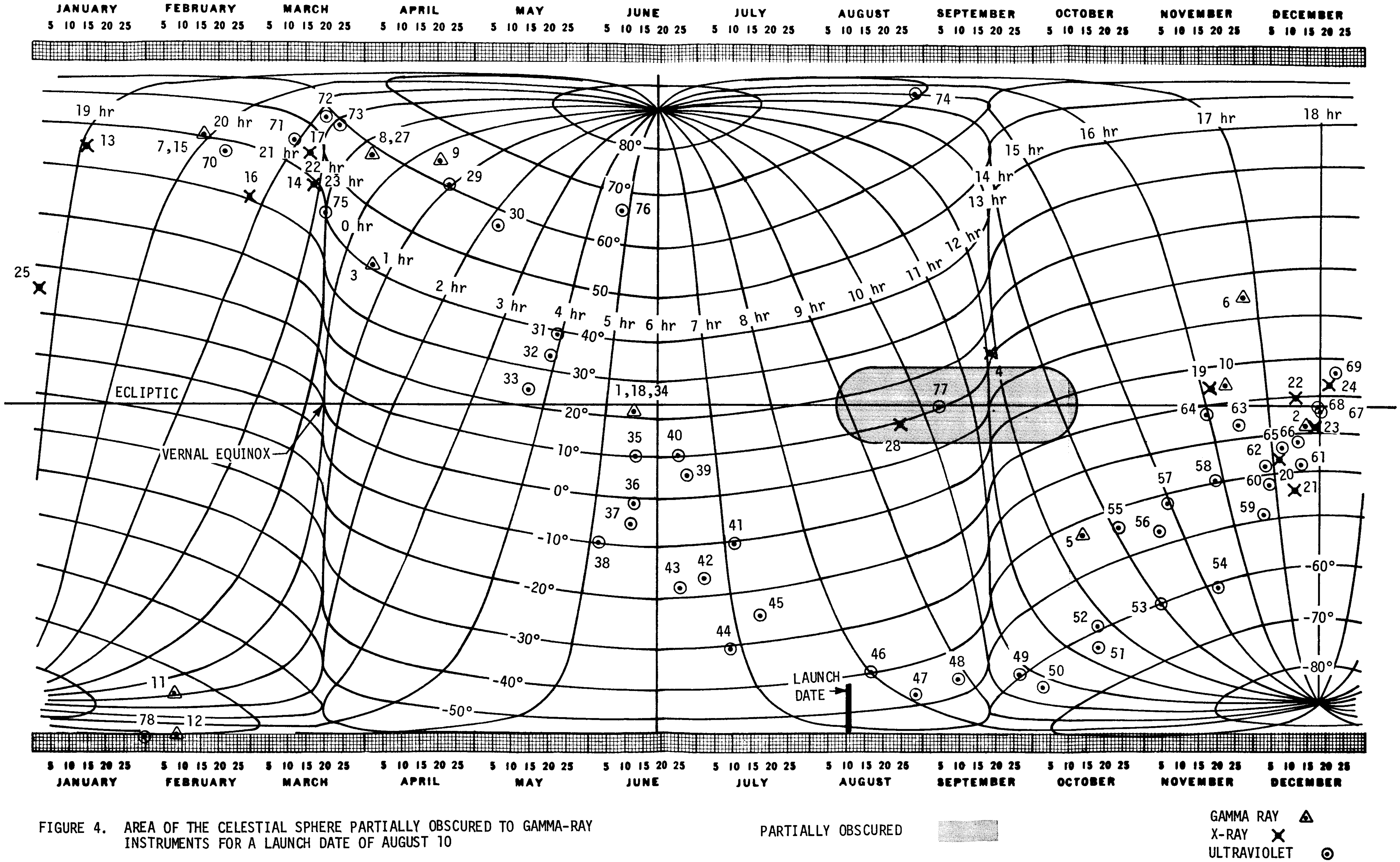


FIGURE 4. AREA OF THE CELESTIAL SPHERE PARTIALLY OBSCURED TO GAMMA-RAY INSTRUMENTS FOR A LAUNCH DATE OF AUGUST 10

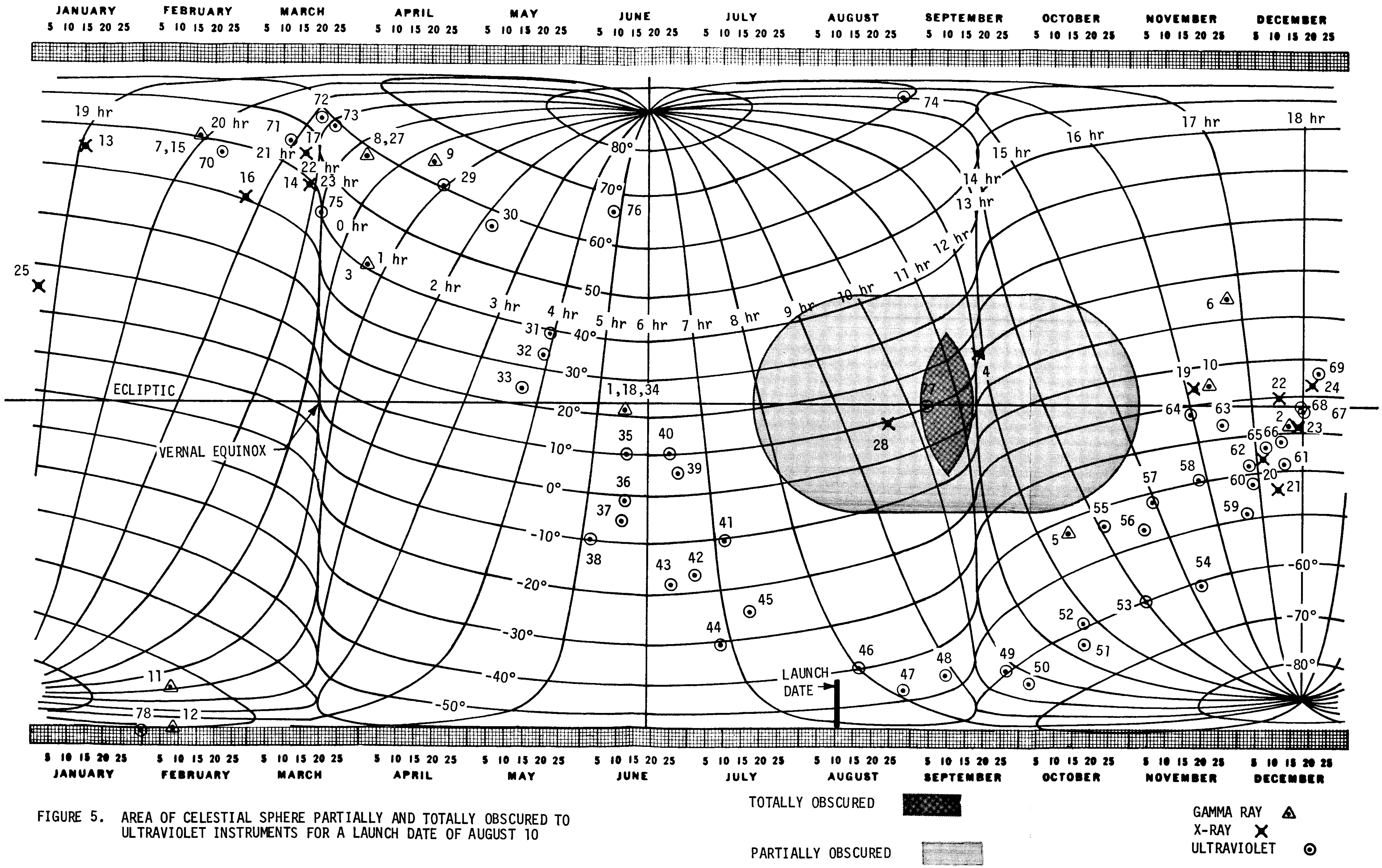


FIGURE 5. AREA OF CELESTIAL SPHERE PARTIALLY AND TOTALLY OBSCURED TO ULTRAVIOLET INSTRUMENTS FOR A LAUNCH DATE OF AUGUST 10

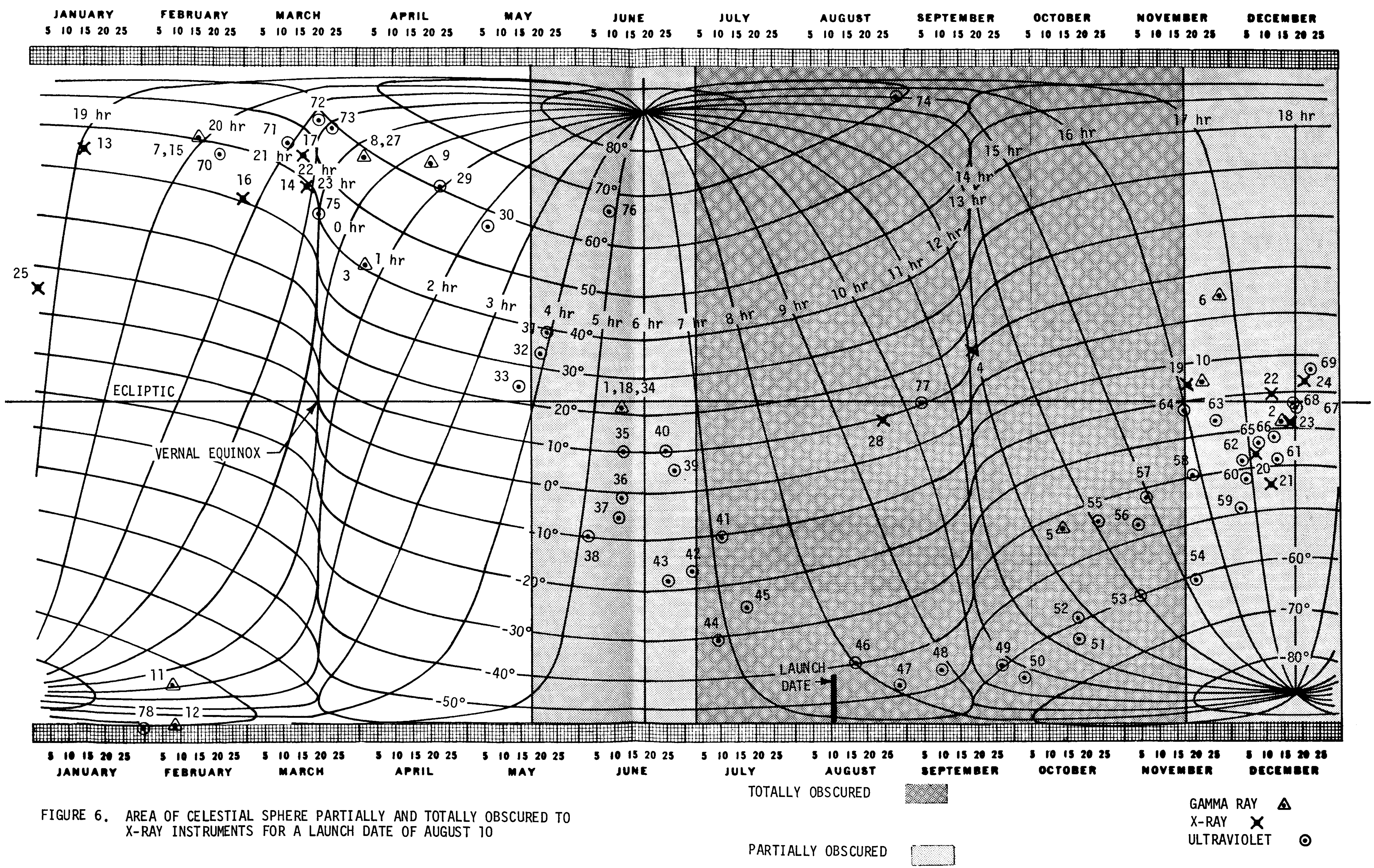


FIGURE 6. AREA OF CELESTIAL SPHERE PARTIALLY AND TOTALLY OBSCURED TO X-RAY INSTRUMENTS FOR A LAUNCH DATE OF AUGUST 10

Because of the apparent motion of the Sun on the ecliptic, different launch dates would correspond to different solar positions. To determine the obscured area at a given time, one would simply place an overlay over Figure 3 with the launch data index on the overlay aligned to the proper date on Figure 3.

In order to use the overlay method, the obscured region must have the same shape and size for various solar positions (different launch dates). Because of the motion of the Sun in declination, this is impossible for any simple right ascension-declination coordinate system on a flat sheet. However, the condition of constant shape and size of the obscured region will be fulfilled if the plot of the celestial sphere is done using ecliptic latitude and ecliptic longitude as rectangular coordinates as shown in Figures 3 through 6. These coordinates are analogous to latitude and longitude as used for the Earth, except that the ecliptic replaces the equator. In this case the obscured areas maintain constant size, shape, and orientation since they remain centered at ecliptic latitude zero.

In the ecliptic latitude and longitude plot, the position of the Sun on the ecliptic corresponds with the date scales. Right ascension and declination coordinates have been transformed and placed on the plot. Ultraviolet, gamma-ray, and X-ray sources are also plotted in their proper positions. The three overlay plots used on Figures 4, 5, and 6 correspond to these types of sources. By tracing the overlay plots on a separate sheet, shifting them parallel to the ecliptic, and positioning them for any other launch date, one may determine the corresponding areas obscured.

Plots of launch date versus the number of X-ray, gamma-ray, ultraviolet, and total number of sources obscured during an entire 56-day mission are given in Figure 7. Since the Crab Nebula is a source of gamma, X, and ultraviolet emissions, it was considered important to be able to view this source during at least a portion of the mission. It was not possible to choose a launch date for which no X-ray sources would be obscured during the entire mission. This is reflected in the X-ray plot of Figure 7. This plot also illustrates that the Crab Nebula will not be visible to the X-ray viewing equipment at any time during the mission if the launch date occurs between March 7 and July 22. This source will be obscured for a portion of the mission for launch dates from January 22 to March 7 and from July 22 to September 4. The Crab Nebula will not be visible to the ultraviolet viewing equipment at any time on a 56-day mission beginning from May 6 to May 23.

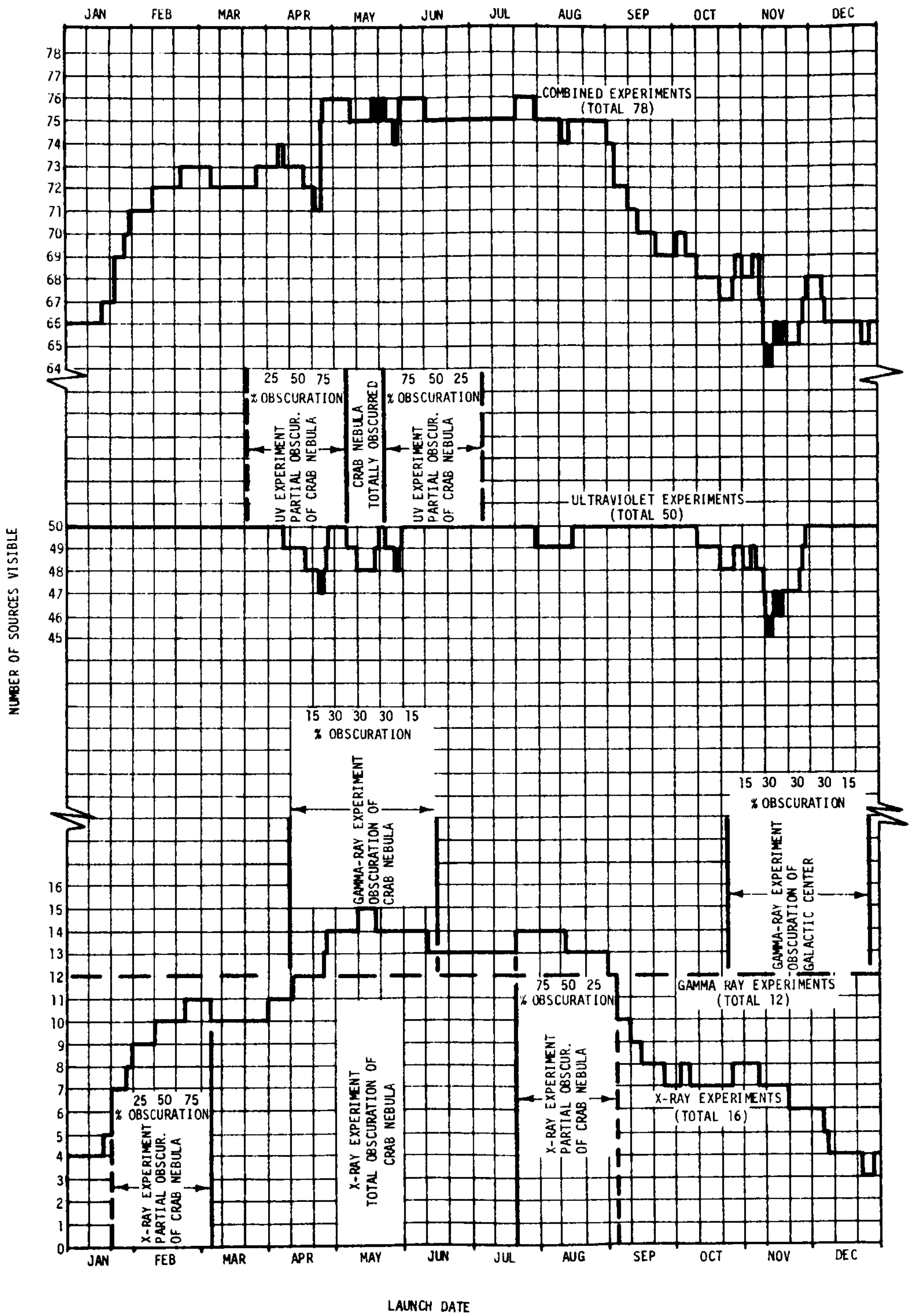


FIGURE 7. LAUNCH DATE VERSUS NUMBER OF SOURCES VISIBLE

Inspection of the plot of total number of visible sources in Figure 7 reveals that it is possible to view a maximum of 76 of the 78 given sources, providing an appropriate launch date is chosen. However, the Crab Nebula will not be visible to X-ray equipment on missions having launch dates from March 7 to July 22. Therefore, the most desirable launch date appears to be sometime between July 22 and August 31. If a launch date between July 22 and July 30 is chosen, 76 sources will be visible, but X-ray visibility of the Crab Nebula will be restricted to less than 25 percent of the mission. If a longer opportunity to view this source is desired, a later launch date could be chosen. A date of August 10 would permit viewing of 75 listed sources and would provide the opportunity to view the Crab Nebula with X-ray equipment at any time during almost 50 percent of the mission duration. Selection of the optimum launch date would be influenced by many factors not considered at this time. A date of August 10 was selected for this study in order to specify the number of visible sources.

D. Experiment Scheduling

The ATM-B experiments can be conducted either in daylight or darkness. For this reason, it has been assumed that all instruments will be on at all times during the mission. In order to estimate the useful experiment time available on this mission, it was assumed that meaningful data could be obtained at any time during the entire 93-minute orbit. Whenever a desired source or scan area is obscured by the Earth, some other visible point source or scan area will be observed.

The arrangement of instruments on both configurations presented in this report permits the conduct of X-ray, gamma-ray and UV experiments simultaneously and independently of one another. The gamma-ray and UV experiments will require a short setup and shutdown operation by a crew member. The run time, or instrument viewing portion of the experiments, requires only periodic monitoring by a crew member. The X-ray experiments require little setup or shutdown time, but for best results one experiment requires the full attention of a crew member during the viewing period. During those periods when two crew members are in the LM, it is possible to conduct three experiments simultaneously. During those periods when only one crew member is in the LM, either an X-ray experiment alone or gamma-ray and/or UV experiment may be conducted.

The astronaut schedules shown in Figure 1 provide 11 hours per day when two men are available for experiments and eight hours per day when one man is available on regular ATM experiment days. If all X-ray experiments are conducted during the time when two men are available for experiments, then seven orbits per day will be available in which X-ray experiments may be conducted and 12 orbits per day will be available in which gamma-ray and UV experiments may be conducted on experiment days. On EVA days, two experimenters will be available for 5 hours and one experimenter will be available for 6 hours. This will provide three orbits during which X-ray experiments may be conducted and seven orbits during which X-ray and/or ultraviolet experiments may be conducted.

A factor in addition to Sun interference which must be considered in determining the visibility of a point source is the ability of the instruments to be pointed in the proper direction. Viewing instruments are located on three separate platforms which may be deployed and pointed independently of each other and for the gamma-ray and ultraviolet platforms, independently of the cluster orientation. The locations of these platforms are shown in Figure 8. The mounting configuration of the X-ray platform determined the size and shape of the X-ray sky plot overlay which, in turn, determined X-ray source visibility on this mission. However, the mounting configurations of the gamma-ray and ultraviolet platforms were not considered in the determination of the size or shape of the overlays for these sources.

The scanning limits of the gamma-ray and ultraviolet platforms are illustrated in Figures 9 through 12. As shown in these figures, the instruments may be pointed in any desired direction. Since the solar panel frames nearest the instruments are open, the panels do not present a significant visibility obstacle. If viewing of a source is blocked by the cluster with the instrument platform in a given position, it will usually be possible by reorienting the boom and platform to obtain an unobstructed view of the desired source. Those small areas of the celestial sphere which may still be obscured by the "shadow" of the cluster regardless of instrument platform orientation can probably be made visible by a single reorientation of the cluster about the solar vector at some time during the mission. For this reason no blocking of sources by the cluster was considered for either the gamma-ray or ultraviolet sources.

1. Gamma-ray Experiments. The required viewing time for each gamma-ray source listed in Table 1 is either 8.33 or 10.00 hours. The total required viewing time is 108.31 hours. It will be possible to

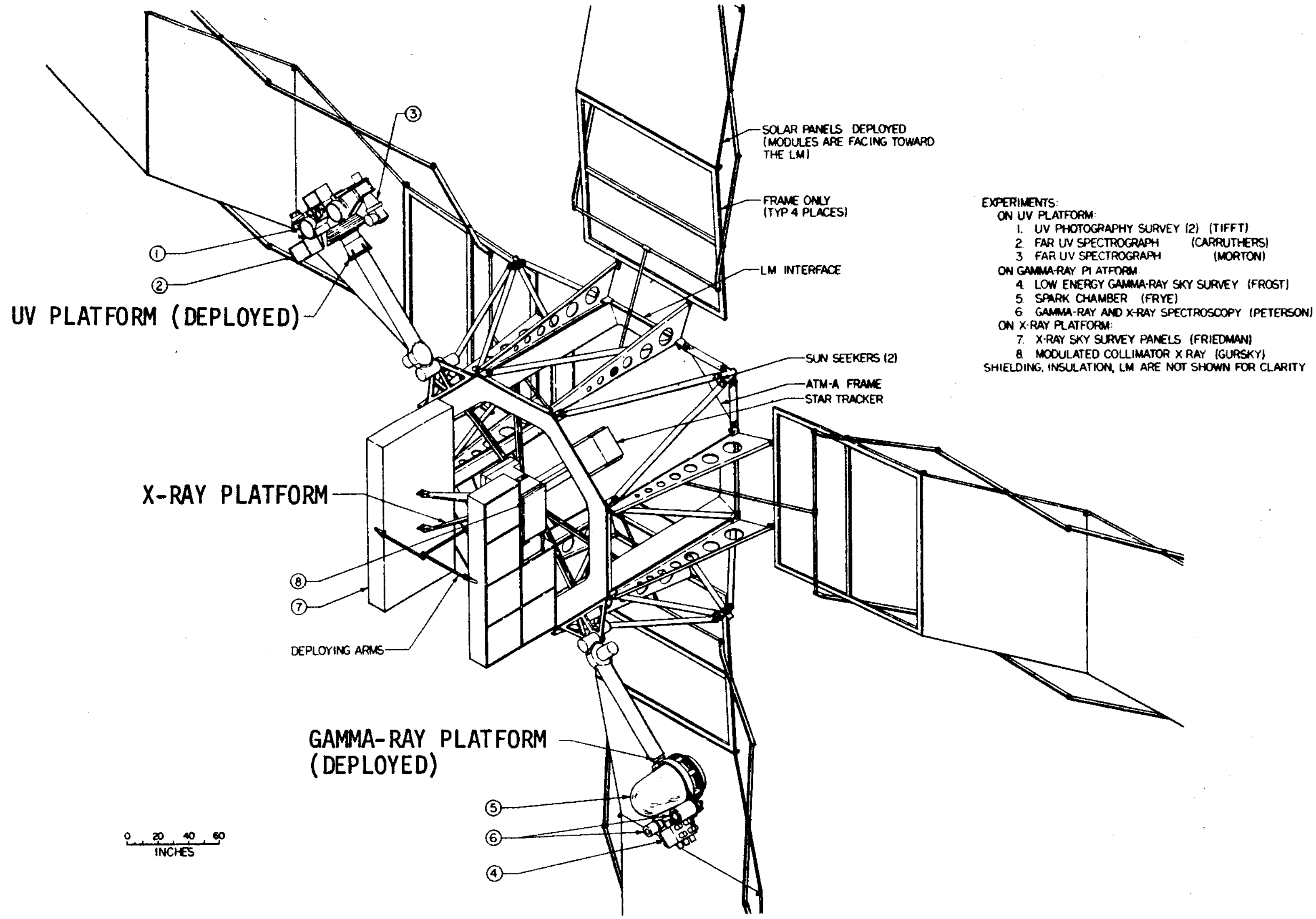


FIGURE 8. LOCATIONS OF UV, X-RAY, AND GAMMA-RAY PLATFORMS

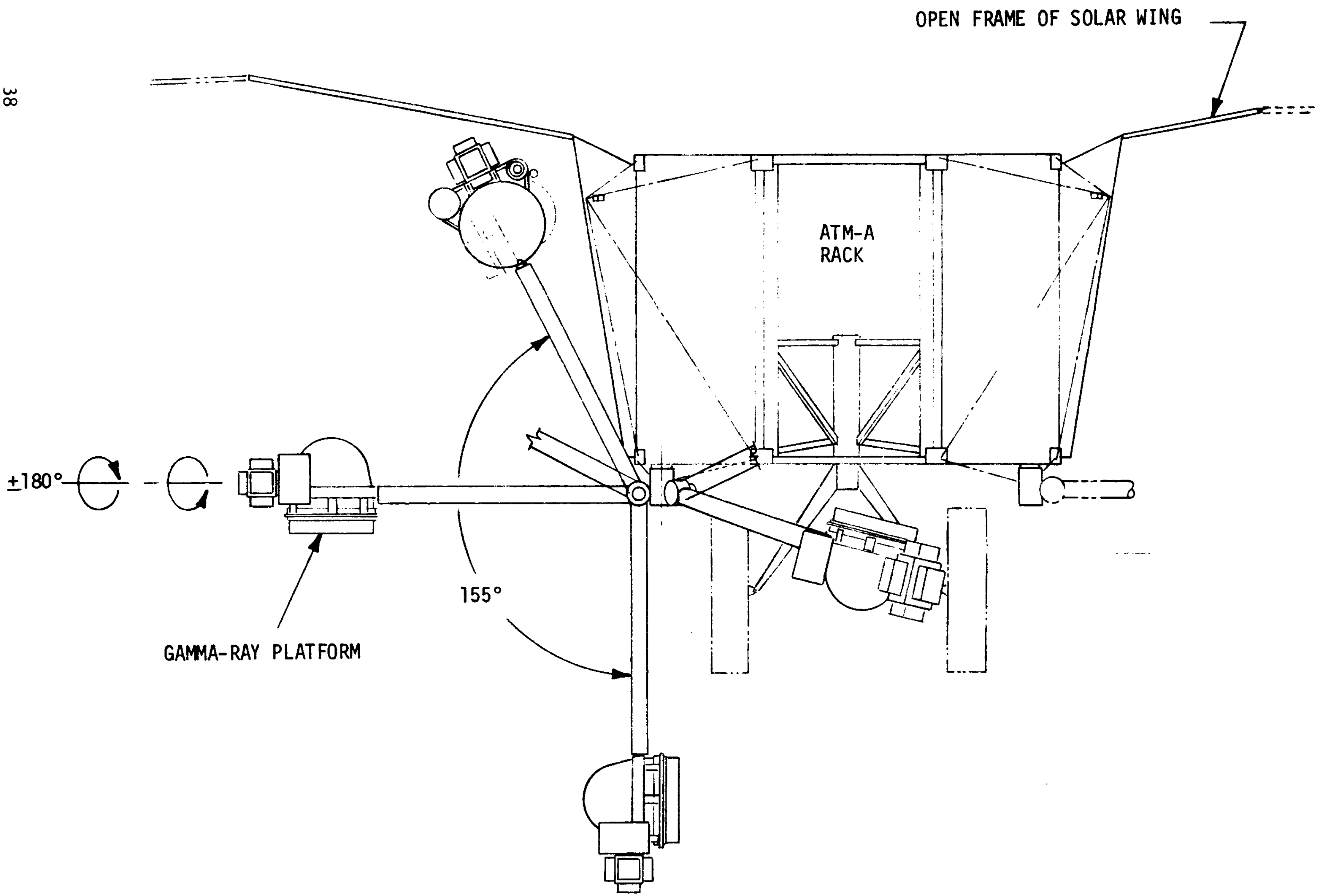


FIGURE 9. SCANNING LIMITS FOR GAMMA-RAY PLATFORM (SIDE VIEW)

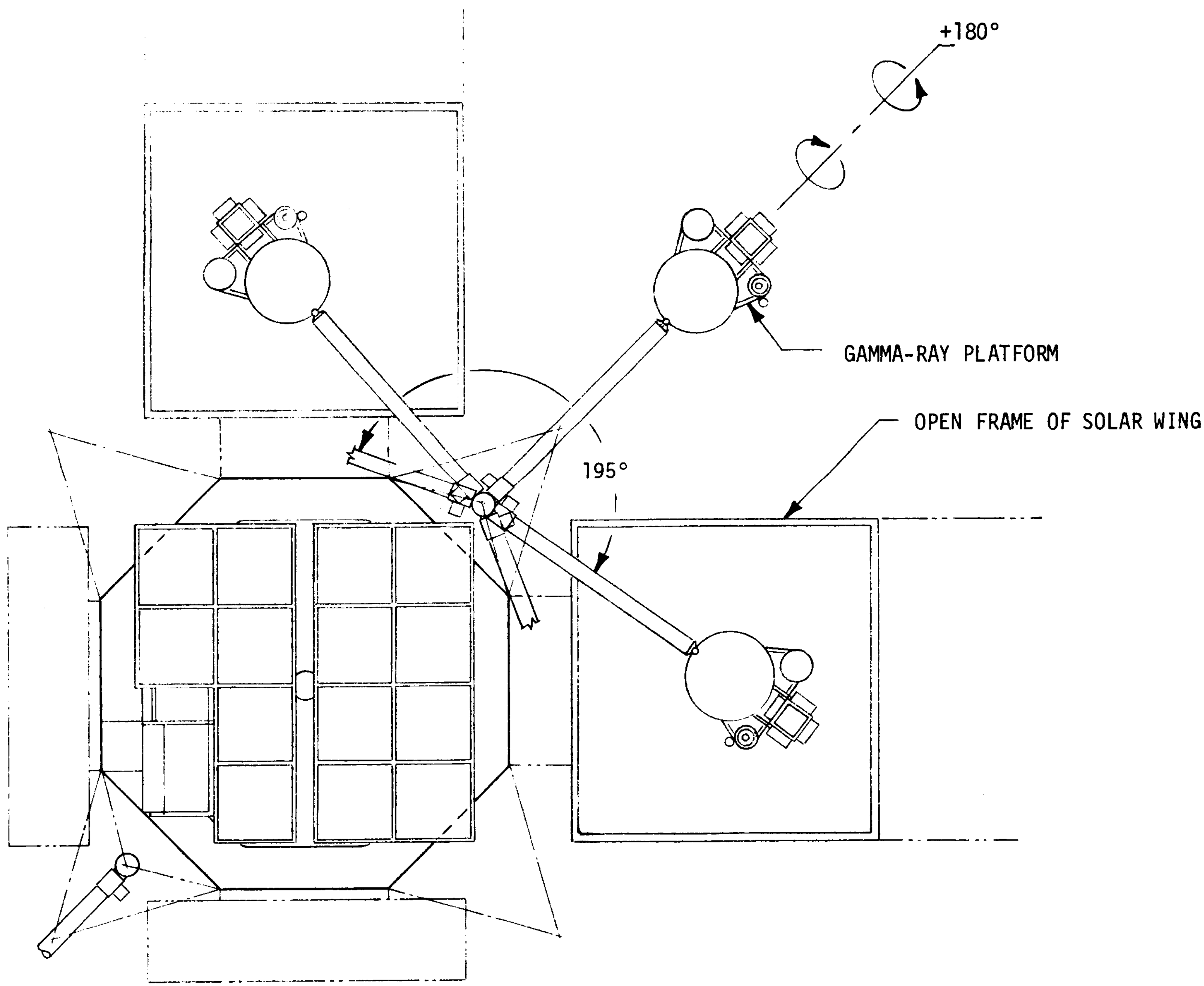


FIGURE 10. SCANNING LIMITS FOR GAMMA-RAY PLATFORM (BOTTOM VIEW)

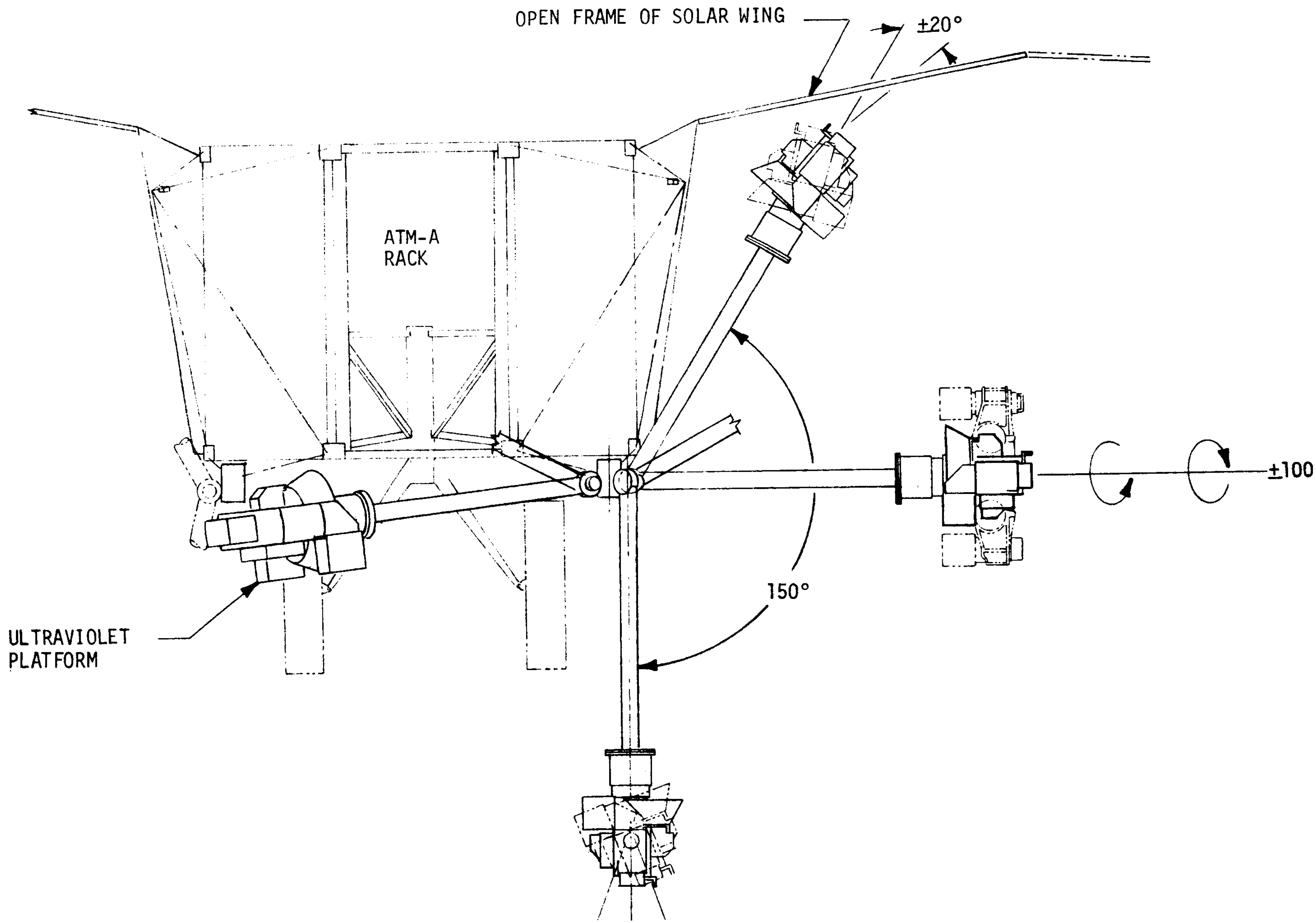


FIGURE 11. SCANNING LIMITS FOR ULTRAVIOLET PLATFORM (SIDE VIEW)

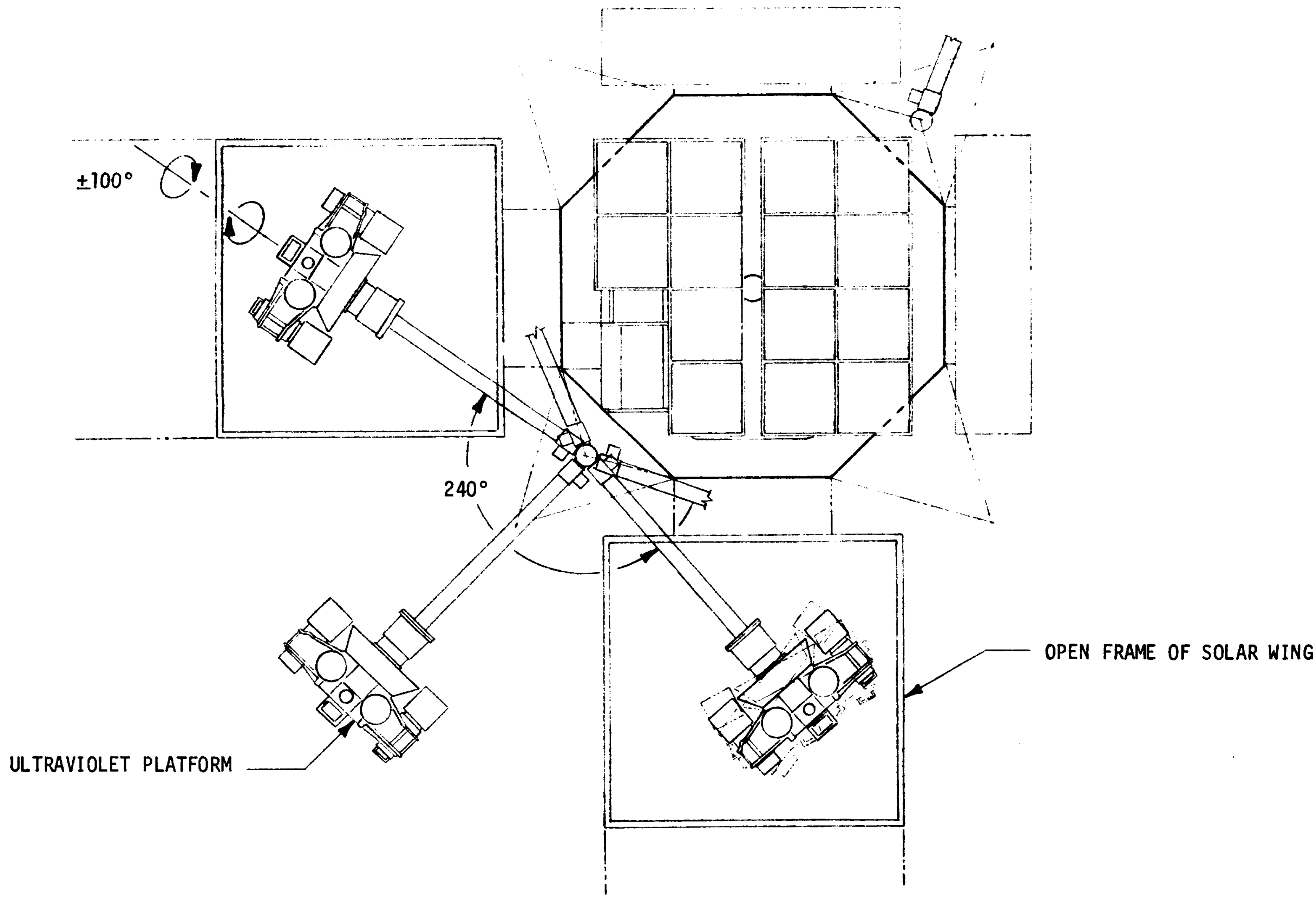


FIGURE 12. SCANNING LIMITS FOR ULTRAVIOLET PLATFORM (BOTTOM VIEW)

view some of the sources continuously for the required time. This will not be possible for other sources due to interference of the Earth during a portion of the orbit. In order to determine the number of mission days required to provide the required gamma-ray source viewing time, a conservative assumption was made that three different sources must be viewed during each orbit (due to Earth interference) and that a 5-minute acquisition and set up time will be required prior to the beginning of each viewing. The orbit period is 93 minutes; subtraction of 15 minutes for source acquisition and experiment set up leaves 78 minutes of viewing time per orbit. The required 108.31 hours of viewing time can be provided in 84 orbits. Following the previously given mission profile and daily astronaut schedules, the gamma-ray source viewing can be completed on the fifth of the 12 orbits available for experiments on mission day 16.

Gamma-ray scan must be conducted at a rate of 1.0 to 1.5 degrees per hour, the field-of-view is 4 degrees. The total number of orbits during the mission when at least one crewman will be available for experiments is 433. If viewing of previously selected gamma-ray sources is performed on 84 orbits, 349 orbits will be available for gamma-ray scan. If scan could not be conducted continuously due to Earth interference and if three different areas are scanned on each orbit, then 349 orbits will provide 454 hours of scan time. This will permit scanning of approximately 64 percent of a 20 by 180-degree field of interest in the galactic plane.

2. X-ray Experiments. All X-ray sources except numbers 26 and 28 will be visible at sometime during the mission. The required total viewing time for the 14 visible sources is 5.17 hours. Again assuming that three different sources must be viewed on each orbit due to Earth interference, thereby leaving 78 minutes of viewing time per orbit, four orbits will be required to view the 14 sources. Since X-ray experiments will be conducted only when two crewmen are available for experiments, the source viewing may be completed on the fourth of the seven orbits available on mission day 8.

X-ray scan rate is limited to 2 degrees per minute by the Gursky experiment and to a 2 by 8-degree field of view by the Friedman experiment if the maximum benefit of both experiments is to be realized. The area of scan is limited to the hemisphere opposite to the Sun's location; however, movement of the Sun during the 46-day observation period of the mission will permit scanning of approximately 225 degrees of the celestial sphere. The time required to scan this area was calculated to be 27 hours providing there is no overlap of scanned areas. If 78 of the 93 minutes orbital period is available for scanning, 21 orbits will be required to provide the desired scan time. If source viewing is completed during the first four orbits of mission day 8, the scan experiment may be completed by the end of the fourth orbit of mission day 11. The sky scan could be completed earlier if the faster scan rate permitted by the Friedman experiment were used. However, the entire visible area may be scanned at the slower rate prior to the end of the mission.

3. Ultraviolet Experiments. All of the 50 ultraviolet sources listed in Table 1 except number 77 will be visible during some portion of the mission. The viewing time for each source is 20 minutes; total viewing time required for the 49 visible sources is 17 hours. If 5 minutes is allowed for the acquisition of each source and for experiment set up, then 3 sources may be viewed during each orbit. Seventeen orbits during which at least one experimenter is available are required to provide the necessary viewing time. Viewing of these sources may be completed by the end of the fifth orbit of mission day 9.

Approximately 2 600 known and suspected ultraviolet sources have been cataloged. Viewing of this number of sources would require 867 orbits. After viewing the 49 visible sources listed in Table 1, an additional 1 248 sources selected from the catalog could be viewed during the remainder of the mission.

4. Summary of Experiment Scheduling Requirements. Table 2 presents a summary of the number of orbits required and the possible completion times of the three types of experiments to be conducted during this mission. Completion of all source viewing experiments is possible in a period of time equivalent to the end of the mission day 16. All X-ray source and scan experiments could be completed by the end of the 11th mission day, provided all sources were visible by that time, and a gamma-ray scan of 64 percent of a band of interest in the galactic plane could be completed by the end of the mission.

TABLE 2. EXPERIMENT ORBIT REQUIRED AND POSSIBLE COMPLETION DATES

Experiment	Point Sources		Sky Scan[1]		
	Required Orbits	Completion Date	Required Orbits	Maximum No. Orbits Available	Completion Date
Gamma-ray	84	Day 16	545[2]	349	------
X-ray	4	Day 8	21	---	Day 11
Ultraviolet	17	Day 9	850	416	------

[1] Viewing of additional sources in the case of ultraviolet experiments.

[2] For a 20 by 180-degree segment of interest in the galactic plane.

SECTION IV. PAYLOAD ANALYSIS

A. Structural and Mechanical

In addition to the overall guidelines in Section I, special attention was exercised regarding the following requirements:

- Provide scanning ability for each experiment platform independent of the others and of the cluster
- Provide maximum utilization of the astronaut time
- Minimize Reaction Control System (RCS) fuel requirements and cluster reorientation time
- Provide maximum scanning ability for all experiment platforms without shading by other experiments or by the solar panels
- Keep the pointing ability of all experiments, especially the X-ray experiments in the galactic plane.

Three independent platforms according to the scientific objectives of the experiments are proposed as follows:

- Gamma-ray platform, containing the gamma-ray experiments and one X-ray spectrometer
- Ultraviolet platform, containing the ultraviolet experiments
- X-ray platform, containing the X-ray experiments.

By this arrangement, since none of the experiments are mounted to the rack, each of these platforms can be operated independently from the cluster. This makes it possible that while one platform is pointed to one selected source, the other platforms may simultaneously view other targets. Any of the platforms can be pointed without cluster reorientation.

Two configurations are presented in this report.

1. <u>Configuration I.</u> The cluster arrangement is shown in Figure 13. Table 3 shows a weight estimate and a comparison of the ATM-A Baseline with this payload. The weight data on the ATM-A Baseline in the table were obtained from AAP Weight Status Report (Ref. 4). Figures 14 through 16 show the experiment layout for this configuration.

For this configuration the ATM-A rack and star tracker are proposed to be used without change. It is necessary to use "Sun seekers." To prevent shading by the LM, the Sun seekers will be located on the outrigger arms.

The power source will be the ATM-A "solar panels" with the following two minor modifications:

(1) The modules will be rotated 180 degrees from their position in ATM-A. They will face toward the LM, point to the Sun, and be parallel to the solar panels of the orbital workshop. Minor modifications of the module support-clips and the length of spacer will be necessary.

(2) The first panel frame on each wing (adjacent to the rack) will have no modules. The remaining panels still provide adequate power (see Section IV, Paragraph B).

The reasons for omitting the "modules" in the first frame are:

- The MDA and LM will shade partially one or more of these panels

- Since the effective side of the modules are facing toward the LM, they are affected by the RCS of the LM.

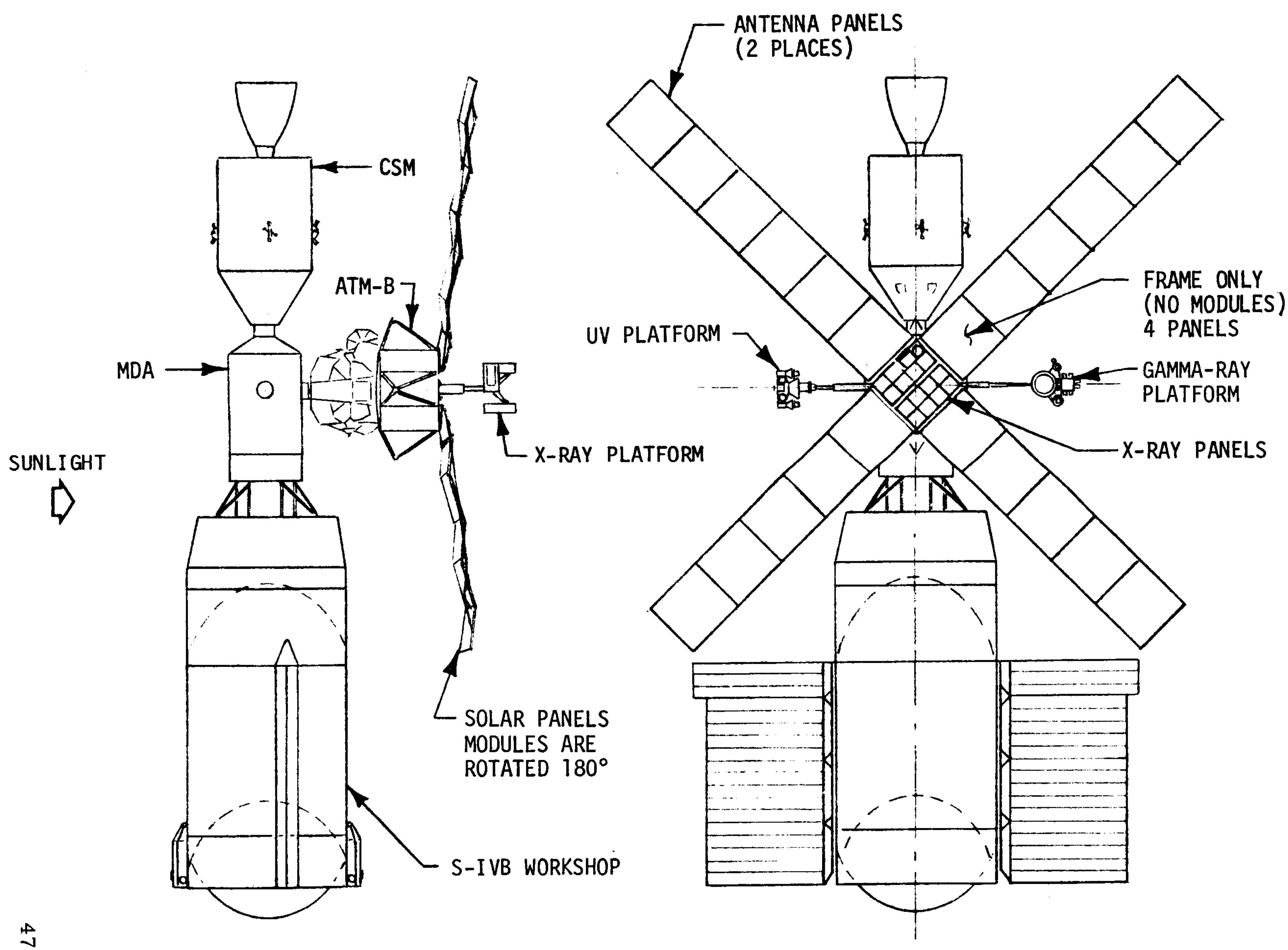


FIGURE 13. CLUSTER ARRANGEMENT WITH ATM-B (Configuration I)

TABLE 3. WEIGHT COMPARISON ATM-A BASELINE VERSUS ATM-B CONFIGURATION I

ATM-A Baseline

Item	Weight (lb)			
TOTAL				32 163
SLA			3 950	
Nose Cap			1 067	
Ascent Stage			9 432	
Structure and System Hardware		5 433		
GFE Equipment		1 356		
Liquids and Gases (excl. prop.)		1 403		
Propellant		1 240		
ATM/Rack			12 363	
Rack Structure		2 207		
Instrumentation and Communication		625		
Control System		1 950		
CMG Equipment and Supports	1 491			
Control Systems Equipment	459			
Electrical Power System		3 157		
Solar Arrays		3 515		
Experiment Support Equipment		105		
Thermal Control System		30		
Miscellaneous		774		
Experimental Package			4 601	
Structure		2 173		
Thermal Control		129		
Experiments		1 952		
H-Alpha Telescope	72			
S052	240			
S053	560			
S054	235			
S055	545			
S056	300			
Electrical Power System		155		
Experiment Support Equipment		79		
Instrumentation and Communication		32		
Control System		81		
Launch Vehicle Modifications			750	

ATM-B Configuration I

Item	Weight (lb)			
TOTAL				32 878[4]
SLA			3 950	
Nose Cap			1 067	
Ascent Stage			9 432	
Structure and System Hardware		5 433		
GFE Equipment		1 356		
Liquids and Gases (excl. prop.)		1 403		
Propellant		1 240		
ATM/Rack			11 947	
Rack Structures		2 207		
Instrumentation and Communication		625		
Control System		1 950		
CMG Equipment and Supports	1 491			
Control Systems Equipment	459			
Electrical Power System		3 157		
Solar Arrays		3 129[1]		
Experiment Support Equipment		105		
Thermal Control System		-0-[2]		
Miscellaneous		774		
Experimental Package			5 732	
Structure (Booms, Platforms, Motors, etc.)		1 200[3]		
Thermal Control		129		
Experiments		4 056		
Ultraviolet Photography Survey (Tifft)	179			
Far Ultraviolet Spectrographs (Carruthers)	62			
Modulated Collimator X-Ray (Gursky)	90			
Low Energy Gamma-Ray Sky Survey (Frost)	200			
Spark Chamber (Frye)	250			
Medium Gamma-Ray and X-Ray Spectrometer (Peterson)	235			
X-Ray Sky Survey (14) Panels (Friedman)	3 040			
Far Ultraviolet Spectrograph (Morton)	62			
Electrical Power System		155		
Experiment Support Equipment		79		
Instrumentation and Communication		32		
Control System		81		
Launch Vehicle Modifications			750	

NOTES:

[1]Four solar panel modules removed adjacent to ATM-A Rack.

[2]Thermal control system removed with canister.

[3]Weight of structure is reduced by eliminating ATM-A support structures of experiments.

[4]Total weight is well below maximum allowable of 34 800 pounds (Ref. 5).

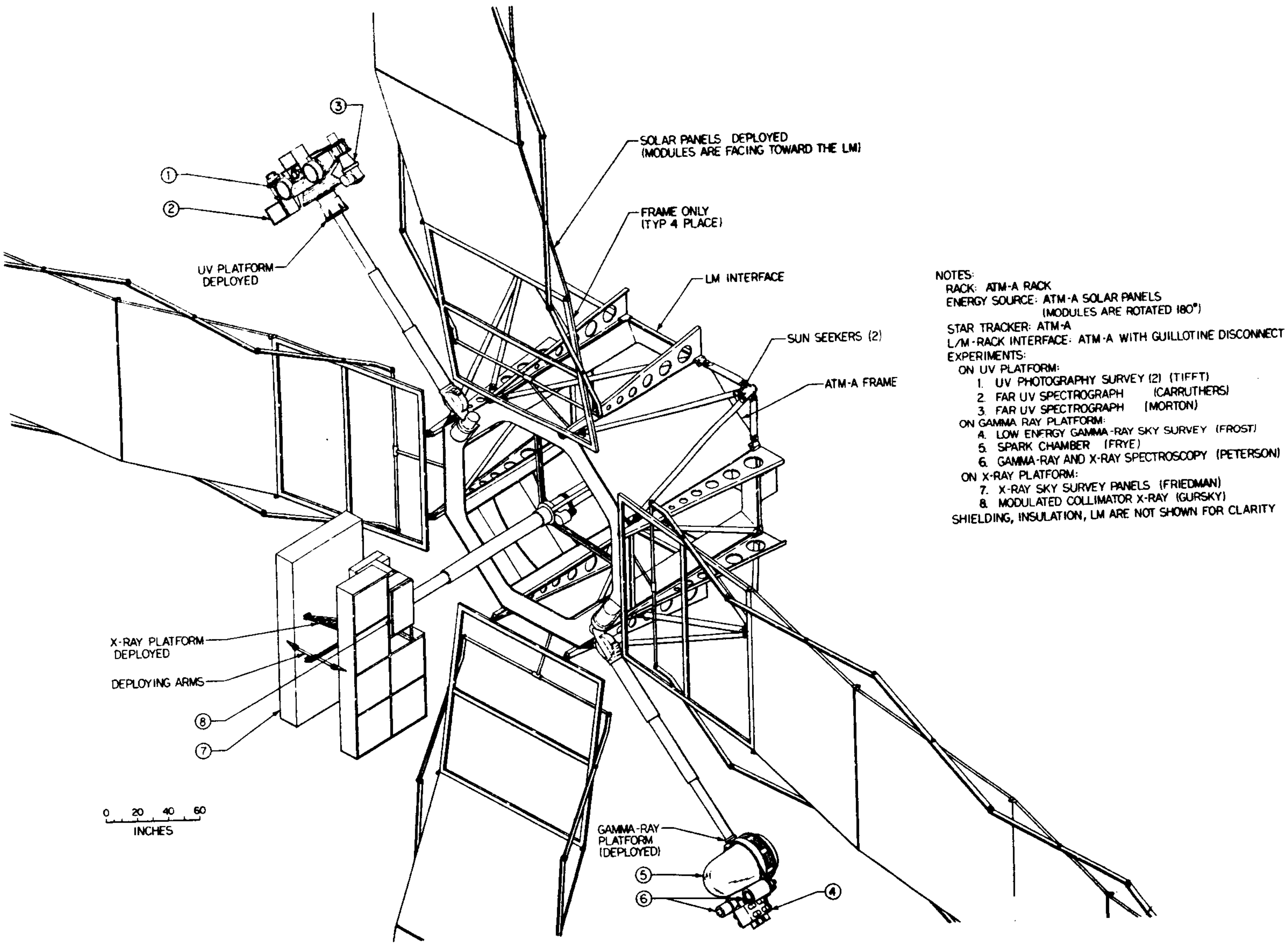


FIGURE 14. ATM-B CONFIGURATION I

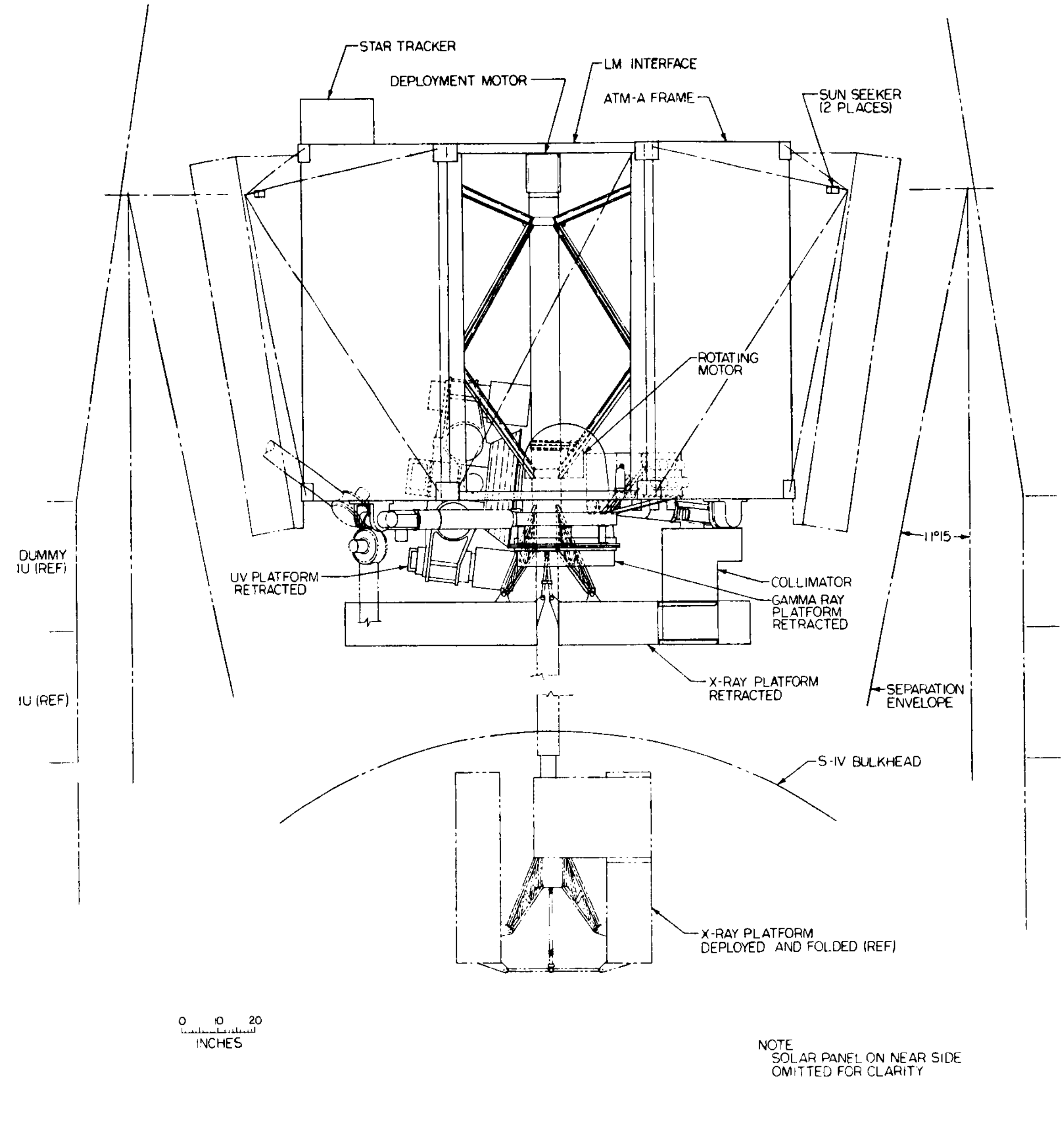


FIGURE 15. ATM-B CONFIGURATION I (SIDE VIEW)

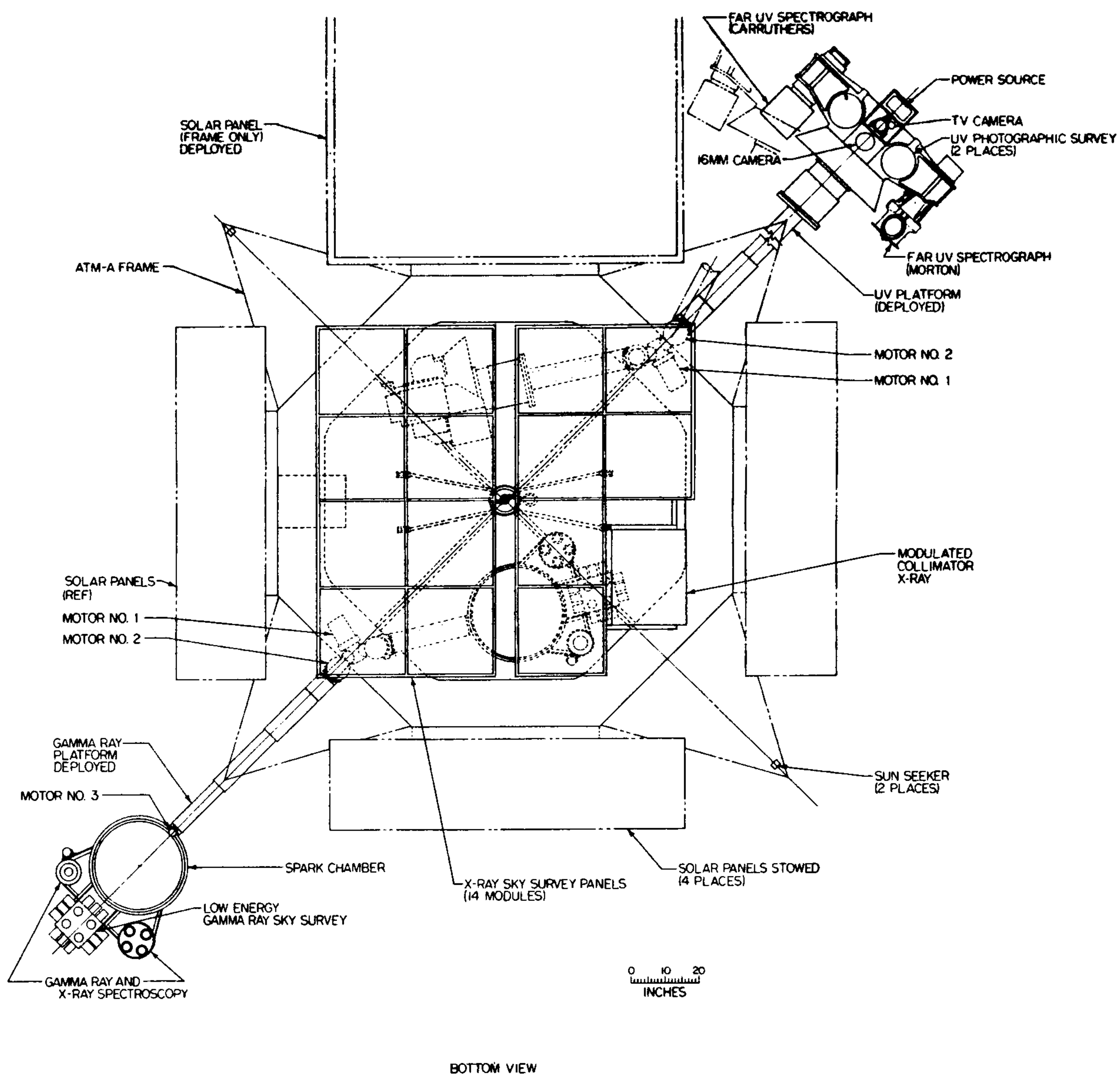


FIGURE 16. ATM-B CONFIGURATION I (BOTTOM VIEW)

In stowed position the ultraviolet and gamma-ray platforms are located partially in the bottom portion of the rack, partially below the rack, and above the X-ray platform, which is located under the rack on a boom. The ultraviolet and gamma platforms will be swung downward after the X-ray platform deployment is completed. It is proposed to apply a safety interlock device so neither the gamma- or ultraviolet-ray platform deployment can start before the X-ray panel deployment provides adequate space.

In stowed position all platforms must be locked to the frame to resist all shock and vibration loads during launch.

The following safety features are proposed:

- All locks, which are to be released by pyrotechnic devices, should have a secondary hand-operated release mode.
- All deployment actions on any platform should have a secondary hand-operated mechanism.
- The RCS should not be fired and all deployment and pointing mechanisms should be de-energized during EVA.
- A working platform (not shown in the figures) should be provided for the astronaut while replacing film in experiments, and all experiment platforms should be locked during film replacement.

Detailed operation of the three platforms are discussed below.

a. Ultraviolet Platform. Three experiments are located on the ultraviolet platform:

(1) Ultraviolet Photographic Survey (Tifft), consisting of three cameras

(2) Far Ultraviolet Spectrograph (Carruthers)

(3) Far Ultraviolet Spectrograph (Morton).

The essential electronics of this experiment are also located on the ultraviolet platform. This platform is deployed by a telescopic boom. Motor No. 1 in Figure 16 provides the swing-down action for boom deployment from its stowed position, and also provides the scanning action from the X-ray panel up to the outrigger arms on the side of the rack through approximately 160 degrees total action.

Motor No. 2 will provide a side motion perpendicular to the previously mentioned action. This motion is advantageous for the ultraviolet and gamma-ray platforms because it helps to eliminate the shading by the X-ray panel deployment boom or the tip of the solar panels. Otherwise, if the required viewing source is behind the X-ray panel, the ultraviolet platform can have clear view only if it is telescoped below the X-ray panels. This telescopic deployment action should be 14 to 16 feet in length. Telescopic motor and deployment mechanism located inside the boom are not shown in Figures 14 through 16.

The stabilized ultraviolet platform is on the telescopic boom with all experiments, electronics, and the television camera. This platform was designed and is being developed by the Astrionics Laboratory of Marshall Space Flight Center and is shown in Figure 17. The ultraviolet platform description and operation is discussed under equipment pointing control, Section IV, Paragraph E.

The astronaut is able to view space by using a position monitor system or possible alternate devices, e.g., "stepper motors" or transducers to indicate the location of the platform. The telescopic motion will be provided by multiextended screws with ball-nut mechanisms inside the boom. The estimated force requirement for deploying the ultraviolet platform is 82 ft-lb maximum.

b. Gamma-ray Platform. Three experiments are located on the gamma-ray platform:

(1) Low-energy Gamma-ray Sky Survey (Frost)

(2) Gamma-ray and X-ray Spectroscopy (Peterson)

(3) Spark Chamber (Frye) or Digitized Spark Chamber (Fichtel).

This platform is also located on a telescopic boom and orientable, but not stabilized. Motor Nos. 1 and 2 and the telescopic mechanism deploy and orient the boom similar to the action for the ultraviolet platform. However, the telescopic motor and deployment mechanism located inside the boom are not shown in the figures.

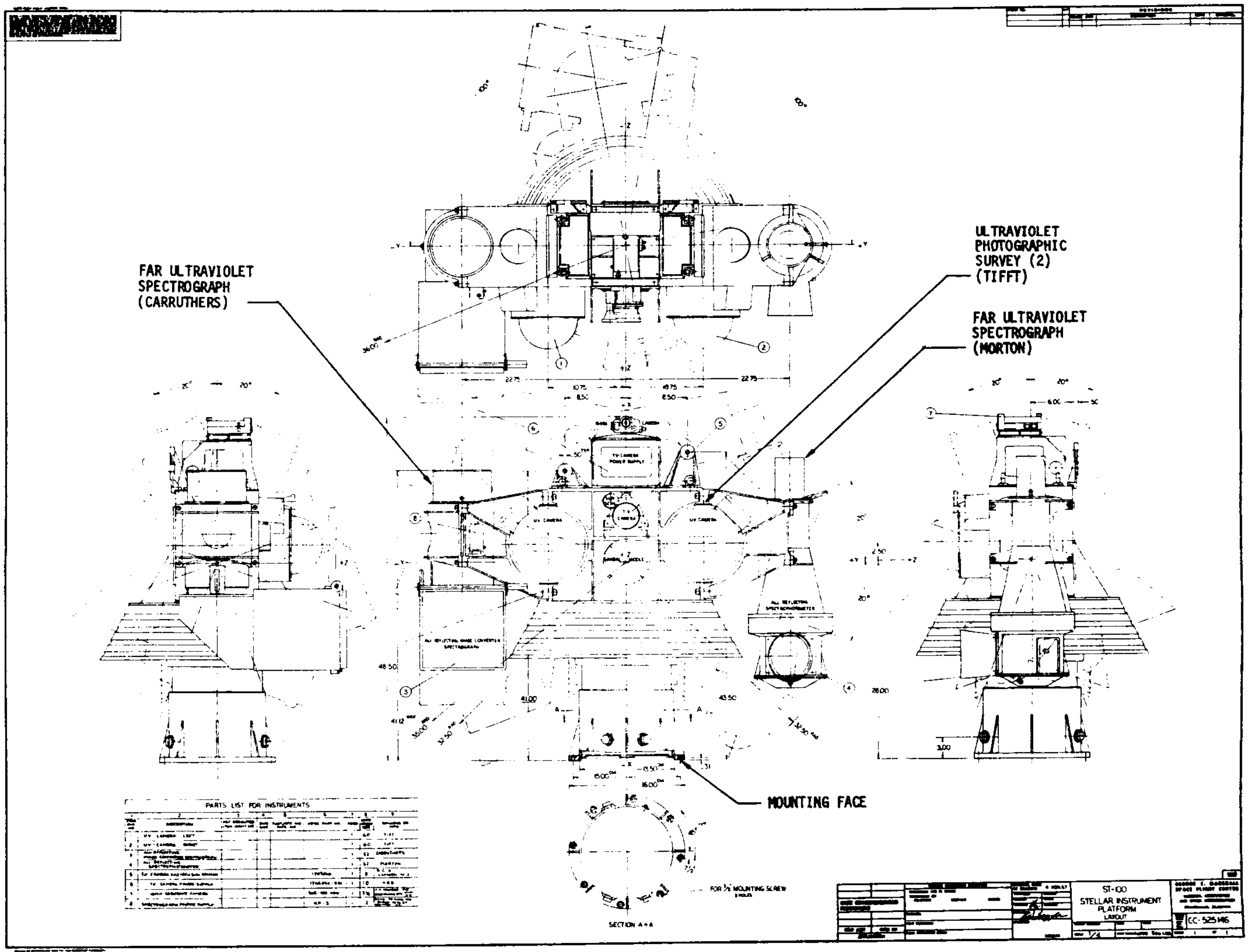


FIGURE 17. STABILIZED ULTRAVIOLET PLATFORM

To provide the necessary experiment roll motion, Motor No. 3, as shown in Figure 16, rotates the platform about the centerline of the boom. Rotation can be 360 degrees. Torque requirement for gamma-ray platform deployment is estimated to be 150 foot-pounds maximum.

c. X-ray Platrorm. The X-ray sky survey (Friedman) and the modulated collimator X-ray (Gursky) are the two experiments located on this platform.

The X-ray sky survey uses 14 panels on two wings with a total area of 56 square feet. This platform is also on a telescopic boom which can be rotated 360 degrees around the boom centerline. The deployment motor turns the multiextended screws, and the telescopic motion will be continued as long as required to provide clear viewing under the solar panel tips. Then the telescope units are locked, and a clamp is disengaged by a pyrotechnic device. After that, the same mechanism will turn the two wings only. Each wing will have approximately 92 to 95 degrees of free motion to prevent any obscured viewing.

Since the boom can be rotated 360 degrees by another motor, the total scanning ability of the X-ray platform will be minimum of one hemisphere. It is necessary to have approximately 130 inches of telescoping deployment to prevent any shading by the antenna tip located on the end of two solar panel wings.

Torque requirement for the X-ray platform is estimated to be 300 foot-pounds maximum. If the gamma-ray and ultraviolet platforms can be turned laterally as shown in Figure 16, they will not cover or be covered by the X-ray panels.

The Modulated Collimator X-ray Experiment is mounted on one wing of the X-ray sky survey panel as shown in Figure 19 and will point in the same direction.

Advantages of this configuration are:

- By locating the experiments on three separate platforms, there is little restriction on pointing other platforms to desired sources.

- Scanning ability for all platforms is adequate.

- Cluster reorientation is not required by any of the three platforms for scanning or pointing.
- Platform rotation requires a reduced amount of power.
- All three platforms work independently of each other and of the cluster.
- The astronaut's time is conserved by his not having to perform frequent cluster reorientation.
- RCS fuel is conserved.
- The amount of material located near the experiments is minimized.

Disadvantages of this configuration are:

- Telescopic deployment for all three platforms is required.
- Vibration on the long booms requires heavy structural members and may delay observation until vibration stops.

2. Configuration II. This configuration proposes to locate the ATM-A solar panels on the top of the rack (on the LM interface side) instead of on the bottom of the rack. With this modification the objectives of the experiment payload can be better accomplished, because larger angles are provided for viewing.

Cluster arrangement for this configuration is shown in Figure 18. Figures 19 through 21 show the experiment layout. Table 4 shows a weight estimate and a comparison to the ATM-A Baseline with this payload.

For this configuration the ATM-A rack is used without change. To relocate the solar panels, a minor structural modification for the solar panel support substructure is necessary because only the deployment mechanism and the pivot point of solar wings must be relocated and rotated 180 degrees, looking toward the LM. Therefore, the wing structure and the deployment mechanism will be unchanged.

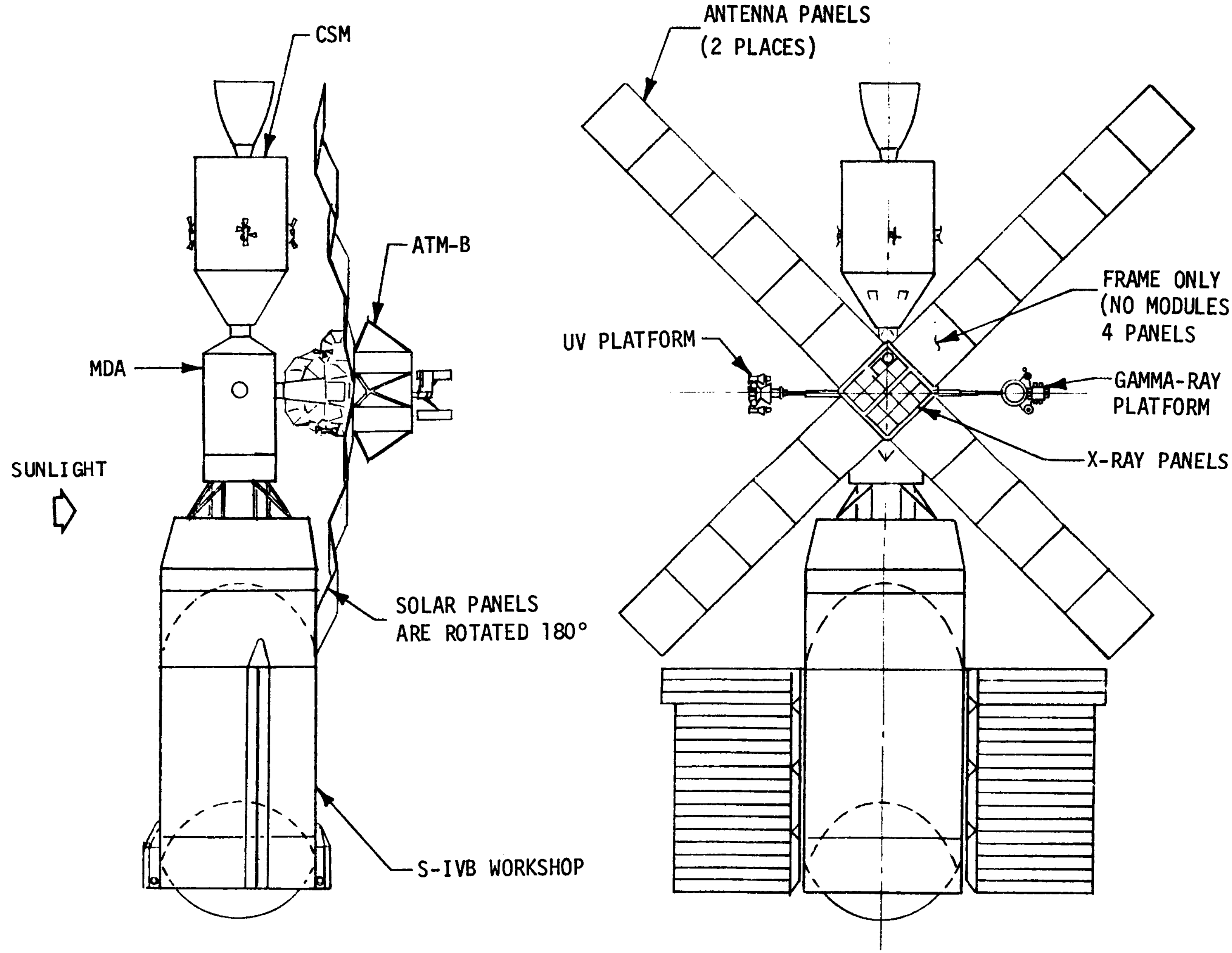


FIGURE 18. CLUSTER ARRANGEMENT WITH ATM-B (CONFIGURATION II)

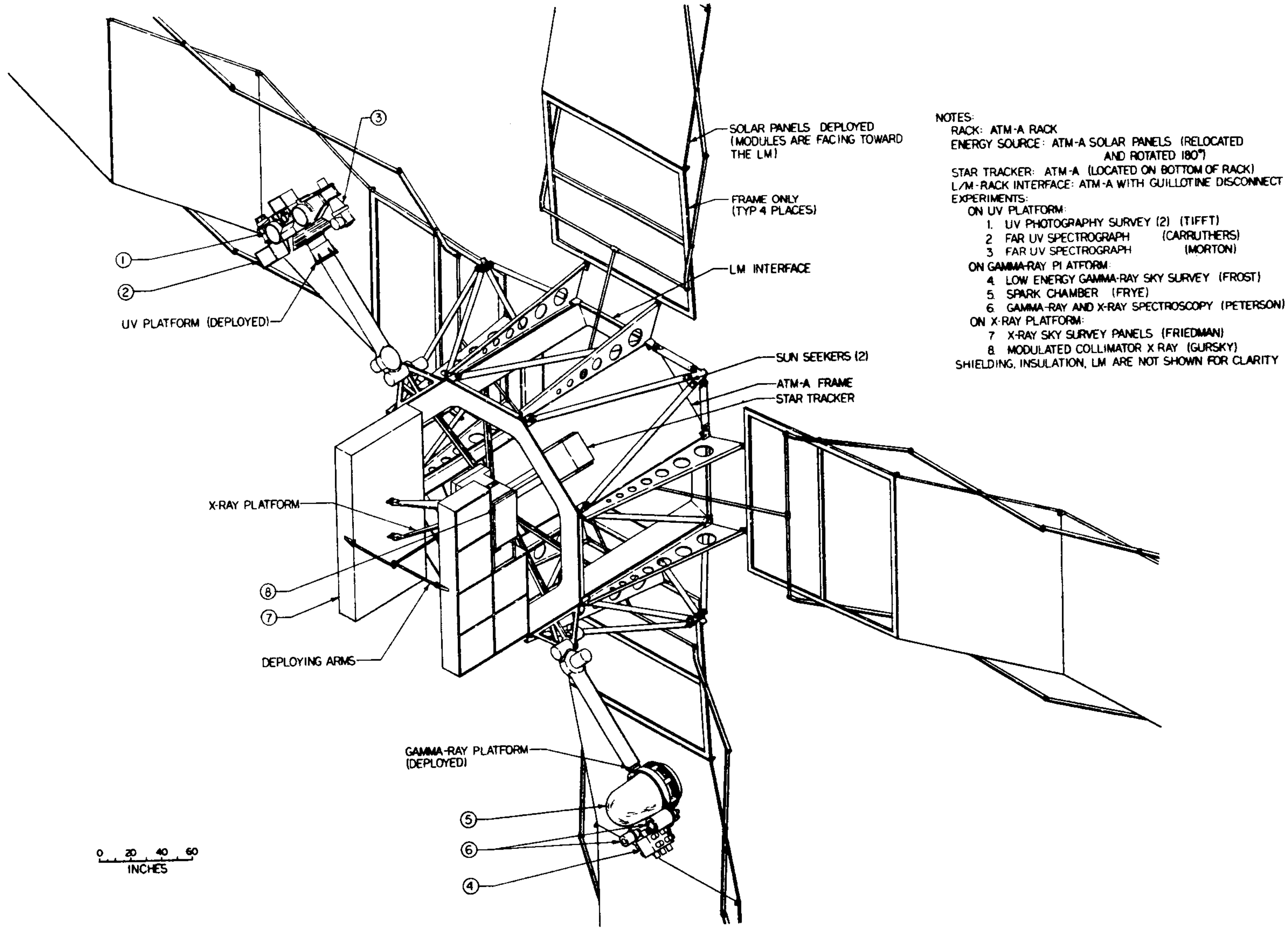


FIGURE 19. ATM-B CONFIGURATION II

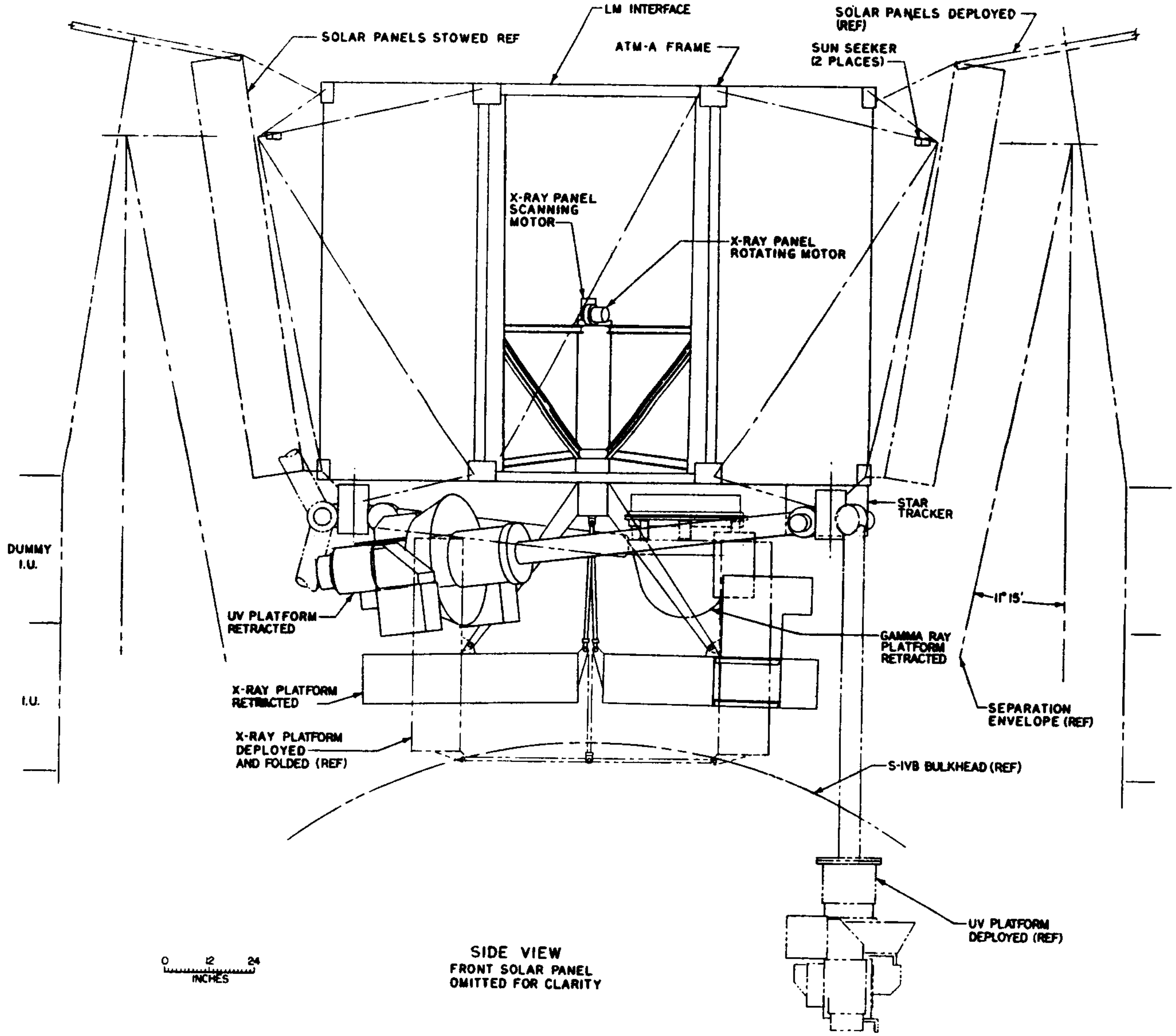


FIGURE 20. ATM-B CONFIGURATION II (SIDE VIEW)

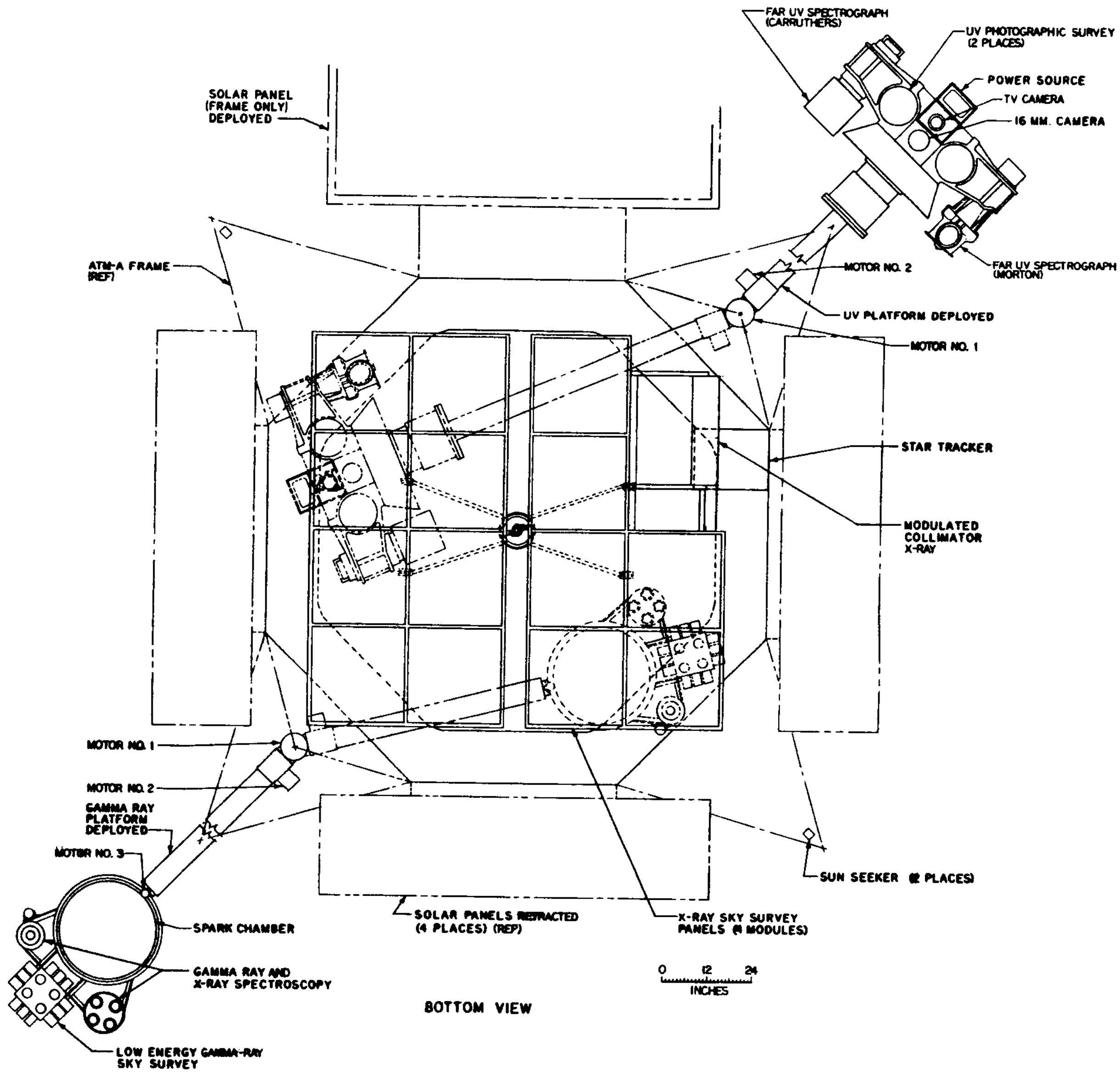


FIGURE 21. ATM-B CONFIGURATION II (BOTTOM VIEW)

TABLE 4. WEIGHT COMPARISON ATM-A BASELINE VERSUS ATM-B CONFIGURATION II

ATM-A Baseline

Item	Weight (lb)			
TOTAL				32 163
SLA			3 950	
Nose Cap			1 067	
Ascent Stage			9 432	
Structure and System Hardware		5 433		
GFE Equipment		1 356		
Liquids and Gases (excl. prop.)		1 403		
Propellant		1 240		
ATM/Rack			12 363	
Rack Structure		2 207		
Instrumentation and Communication		625		
Control System		1 950		
CMG Equipment and Supports	1 491			
Control Systems Equipment	459			
Electrical Power System		3 157		
Solar Arrays		3 515		
Experiment Support Equipment		105		
Thermal Control System		30		
Miscellaneous		774		
Experimental Package			4 601	
Structure		2 173		
Thermal Control		129		
Experiments		1 952		
H-Alpha Telescope	72			
S052	240			
S053	560			
S054	235			
S055	545			
S056	300			
Electrical Power System		155		
Experiment Support Equipment		79		
Instrumentation and Communication		32		
Control System		81		
Launch Vehicle Modifications			750	

ATM-B Configuration II

Item	Weight (lb)			
TOTAL				32 478[4]
SLA			3 950	
Nose Cap			1 067	
Ascent			9 432	
Structure and System Hardware		5 433		
GFE Equipment		1 356		
Liquids and Gases (excl. prop.)		1 403		
Propellant		1 240		
ATM/Rack			11 947	
Rack Structures		2 207		
Instrumentation and Communication		625		
Control System		1 950		
CMG Equipment and Supports	1 491			
Control Systems Equipment	459			
Electrical Power System		3 157		
Solar Arrays		3 129[1]		
Experiment Support Equipment		105		
Thermal Control System		-0-[2]		
Miscellaneous		774		
Experimental Package			5 332	
Structure (Booms, Platforms, Motors, etc.)		800[3]		
Thermal Control		129		
Experiments		4 056		
Ultraviolet Photography Survey (Tifft)	179			
Far Ultraviolet Spectrographs (Carruthers)	62			
Modulated Collimator X-Ray (Gursky)	90			
Low Energy Gamma-Ray Sky Survey (Frost)	200			
Spark Chamber (Frye)	250			
Medium Gamma-Ray and X-Ray Spectrometer (Peterson)	235			
X-Ray Sky Survey (14) Panels (Friedman)	3 040			
Far Ultraviolet Spectrograph (Morton)	62			
Electrical Power System		155		
Experiment Support Equipment		79		
Instrumentation and Communication		32		
Control System		81		
Launch Vehicle Modifications			750	

NOTES:

[1] Four solar panel modules removed adjacent to ATM-A Rack.

[2] Thermal control system removed with canister.

[3] Weight of structure is reduced by eliminating ATM-A support structures of experiments.

[4] Total weight is well below maximum allowable of 34 800 pounds (Ref. 5).

The first panel frame will have no solar cells as in Configuration I.

The relocation of the solar panels also dictates the relocation of the ATM-A "Star Tracker", which will be on the bottom of the rack. The viewing angle to the side will remain the same. The star to which the ATM-B should be oriented is not determined at present. The star tracker's viewing angle direction can be changed by mounting modification.

As in ATM-A and Configuration I, two "Sun Seekers" are used in this configuration. Their location is described in Configuration I. The LM/Rack interface will be the same as the ATM-A LM/Rack interface. This configuration is a similar but simplified version of Configuration I. The simplication is possible because the solar panels are relocated. It is proposed in this configuration to use the same three independent platforms proposed in Configuration I.

Each of these platforms can be operated independently of each other and of the cluster. In stowed position all the platforms are located under the rack on nontelescopic booms. The telescopic deployment mechanism on all three platforms is eliminated.

While the X-ray platform remains in a fixed position, the ultraviolet and gamma-ray platforms swing out to the side. In stowed position all platforms must be locked to the frame to resist all shock and vibration loads during launch. The proposed safety features described in Configuration I are applicable to this configuration. Detail operation of the three platforms is discussed below.

a. Ultraviolet Platform. The same three experiments are located on the ultraviolet platform as in Configuration I. The platform is on a nontelescopic boom. This platform was designed and developed by the Astrionics Laboratory of MSFC. This platform and its pointing capability are described in Configuration I.

The boom is rotated laterally by Motor No. 1, Motor No. 2 will rotate the platform upward toward the LM or downward toward the X-ray platform. Motor No. 1 moves the boom laterally to provide clear viewing for the other experiments, and eliminate any shading by the other platforms. Rotation about the boom axis is provided by a mechanism inside the ultraviolet platform described previously.

Because of the rotation of the X-ray platform, there is some possibility that the ultraviolet or gamma-ray platform (or their booms) will partially shade the X-ray platform. Since these two platforms can also be pointed to sources on the side of the rack and above the X-ray panels, the shading of the X-ray platform can be avoided. Scanning on the side of the rack in this configuration is possible also since the solar panels are located on the top of the rack and out of the way.

The astronaut is able to view space by using a position monitor system or possible alternate devices, e.g., "steppers motors" or transducers to indicate the location of the platform. The estimated force requirement for deploying the ultraviolet platform is 40 foot-pounds maximum.

b. Gamma-ray Platform. The same three experiments are located on the gamma-ray platform as in Configuration I. This platform is also located on a nontelescopic boom. Operation and scanning ability is described in Configuration I. Torque requirement for gamma-ray platform deployment is estimated to be 40 foot-pounds maximum.

c. X-ray Platform. The same two experiments are located on this platform as in Configuration I. The operation is similar to Configuration I except there is no telescopic action. Since the boom can be rotated 360 degrees and the wings swung to approximately 92 to 95 degrees, the total scanning ability of the X-ray platform will be a minimum of one hemisphere. The torque requirement for the X-ray platform is estimated to be approximately 200 foot-pounds maximum.

Advantages of Configuration II are:

- All advantages as pointed out in Configuration I are applicable to this configuration.
- Simple design and mechanism.
- No telescopic action is employed.
- Shorter booms permit the use of light weight tubing.

- The mechanism and booms are of lighter weight and require less torque than in Configuration I. Total weight saving is 400 pounds.

- Shorter cables can be used because the solar panels are closer to the LM; therefore, there is a power savings which is estimated to be approximately 100 watts.

- Better viewing ability is provided because the ultraviolet and gamma-ray platforms can scan on the side of the rack without being shaded by the solar panels.

- The heavy solar panels are closer to the thrusters; therefore, the center of gravity of ATM-B will be closer to the OWS and MDA centerline.

- Since no telescopic action is employed, the "working platforms" for the astronauts can be located on the booms.

- EVA is simpler and safer by not having solar panels near the platforms.

- Because the platforms are located on solid members which have no telescopic action, vibration of the platforms can be minimized.

B. Power

1. Introduction. A solar cell array-rechargeable battery system is recommended for ATM-B. Solar cell arrays are highly reliable and thoroughly proven power systems for space applications. They require large surface areas (one square foot produces approximately 10 watts) which involve stowage, deployment, orientation, and drag difficulties. In spite of these difficulties a solar cell array-rechargeable battery power system excels for an open-end mission; no major problem areas are anticipated for the identified size and power level.

2. Power Requirements. The power requirements for the ATM-B system are presented in Table 5. In determining power requirements, the operational mode is of the most interest. This operational mode is divided into two basic parts, sunlight and dark. Within these two there are variations which depend on equipment demands.

3. System Description. The ATM-B power system consists of the primary power source, a solar-cell array, and a secondary battery subsystem including the associated battery chargers, regulators, control, protection, and display equipment. The solar panels provide the required power to the load and to charge the batteries during the time the spacecraft is in sunlight. Power is supplied by the batteries when the solar panel voltage drops below the battery open circuit voltage which occurs during the dark time period, during peak load requirements, and before the deployment of the solar panels.

Each battery unit, which includes the regulators and associated electronics, has a weight of 85 pounds and volume of 1 130 cubic inches. The total battery weight would be 1 700 pounds and will occupy a volume of 13 cubic feet.

4. Solar-cell Array Configuration. Various array configurations can be used to satisfy the power requirements of ATM-B. To minimize cost and development time, the proposed solar array configuration is similar to that of ATM-A (Ref. 6 and 7). It consists of four wings oriented 45 degrees to the S-IVB axis. There are four panels per wing, two sources per panel, and ten modules per source. The array used for ATM-A differs in that there are five panels per wing. The ATM-A solar panels have recently been upgraded. Therefore, the power requirements for this payload can be met by using only 16 panels, rather than 20 panels as on ATM-A.

TABLE 5. ATM-B POWER REQUIREMENTS

	Average Power (watts)						Peak Power (watts)
	Sunlight			Dark			
TOTAL			3 267			3 385	
Pointing Control System		1 140			1 258		
CMG Subsystem	460			460			759
Inertial Platform and Electronics	150			150			250
Star Tracker	30			30			45
Acquisition Sun Seeker	4			-0-			18
Fine Sun Sensor	8			-0-			21
Actuators	150			150			150
Rate Gyro and Heater	28			28			97
Control Computer Assembly	150			250			1 200
Digital Computer and Input/Output Assembly	160			160			160
Stepping Motors and Transducers	-0-			30			30
Instrumentation and Communications		570			570		
Lunar Module Ascent Stage		600			600		
Control and Display		75			75		
Electrical System		234			234		
Master Measuring Voltage Supply (2)	24			24			24
Distribution and Line Loss	210			210			210
Experiments		238			238		
Ultraviolet Photography Survey (Tifft)	20			20			64
Far-Ultraviolet Spectrograph (Carruthers)	2			2			50
Modulated Collimator X-Ray (Gursky)	7			7			11
Low-Energy Gamma-Ray Sky Survey (Frost)	18			18			18
Spark Chamber (Frye)	50			50			100
Gamma-Ray and X-Ray Spectroscopy (Peterson)	10			10			10
X-Ray Sky Survey Panels (Friedman)	130			130			130
Far Ultraviolet Spectrograph (Morton)	1			1			56
Thermal Control		300			300		
Miscellaneous Small Demands		110			110		

C. Instrumentation and Communications

1. Introduction. The instrumentation and communications (I&C) subsystem for ATM-B is located on the ATM rack and is independent of the LM ascent stage I&C subsystem (Figure 22). This system will:

- Satisfy the requirements of ATM-B for which it is specifically designed
- Use highly reliable, flexible, flight proven Saturn hardware
- Require no substantial interface between the rack and the LM ascent stage
- Use Saturn data formats and radio frequencies to maintain compatibility with existing ground station capabilities
- Provide continuous orbital coverage of all scientific data and selected housekeeping data via onboard recording and playback by the auxiliary storage and playback assemblies (ASAPs)
- Provide a command up-link capability for checkout and activation of systems during prelaunch and initial mission operations, and subsequent to orbital storage
- Provide a closed-circuit television system for experiment monitoring and targeting
- Provide the most feasible methods for factory, prelaunch, and orbital checkout of ATM-B systems and provide maximum compatibility with existing prelaunch checkout equipment
- Minimize training requirements for MSFC, KSC, and contractor personnel.

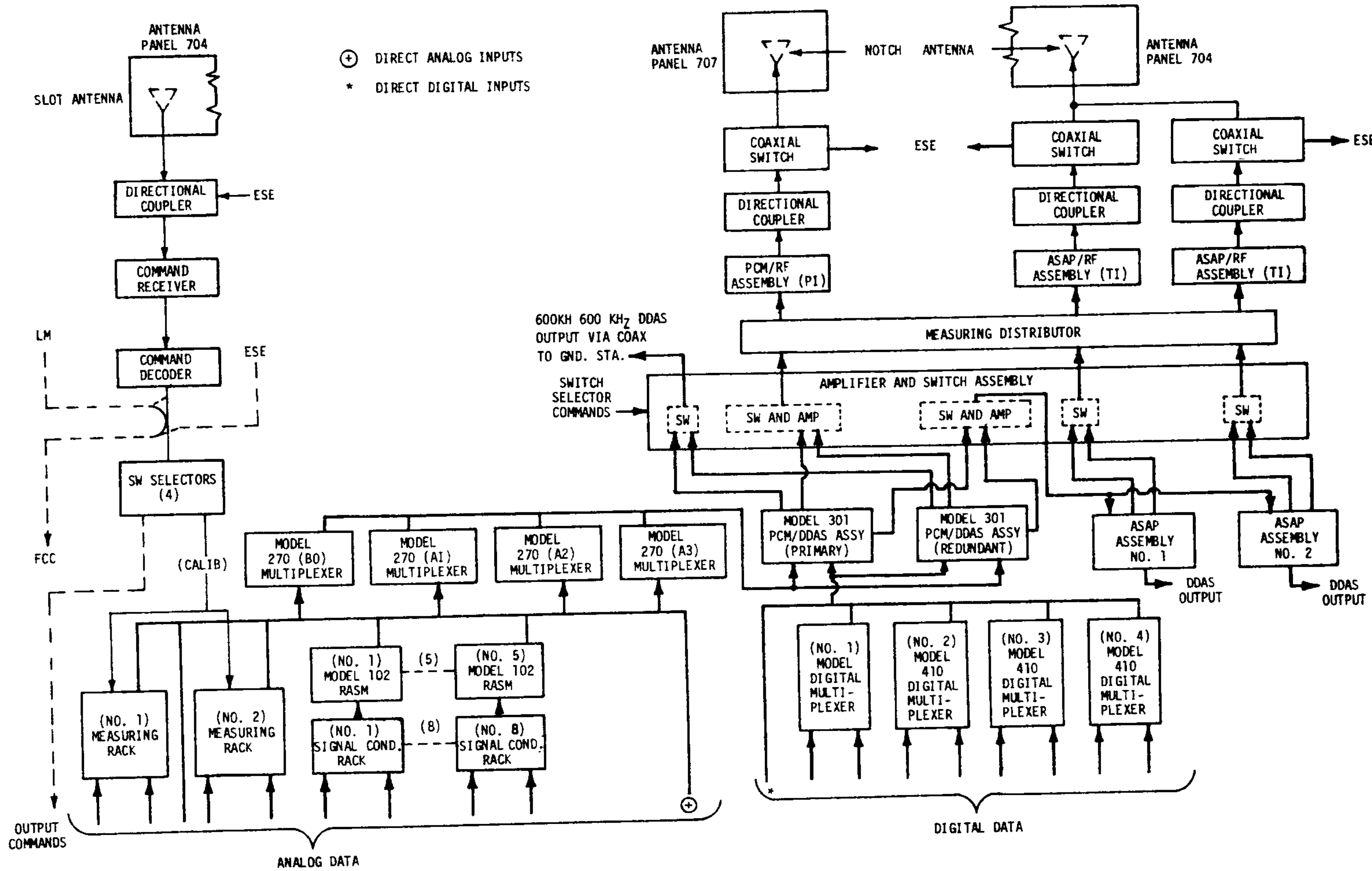


FIGURE 22. INSTRUMENTATION AND COMMUNICATION SYSTEM BLOCK DIAGRAM, ATM-B

2. Measurement-telemetry Requirements. Experiment and ATM-B subsystems measurements-telemetry requirements (itemized in Tables A-3 and A-4 of the Appendix) present a real time telemetry data-rate of 35.3 kilobits per second (kbits/sec); this is well within the pulse code modulator (PCM) system capacity of 72 kbits/sec.

A 6.4 kbit/sec data recording rate is required for the science and selected subsystem housekeeping data. Each ASAP can record data at 4 kbits/sec for up to 90 minutes, with playback and transmission via ASAP/RF assembly at 72 kbits/sec by astronaut or ground command in 5 minutes over a ground station. A pair of ASAPs and ASAP/RF assemblies are provided to meet the 6.4 kbits/sec recording requirement.

The PCM/RF assembly provided for real time telemetry transmission, and the two ASAP./RF assemblies for transmission of recorded data are driven through a switching network to provide a degree of redundancy

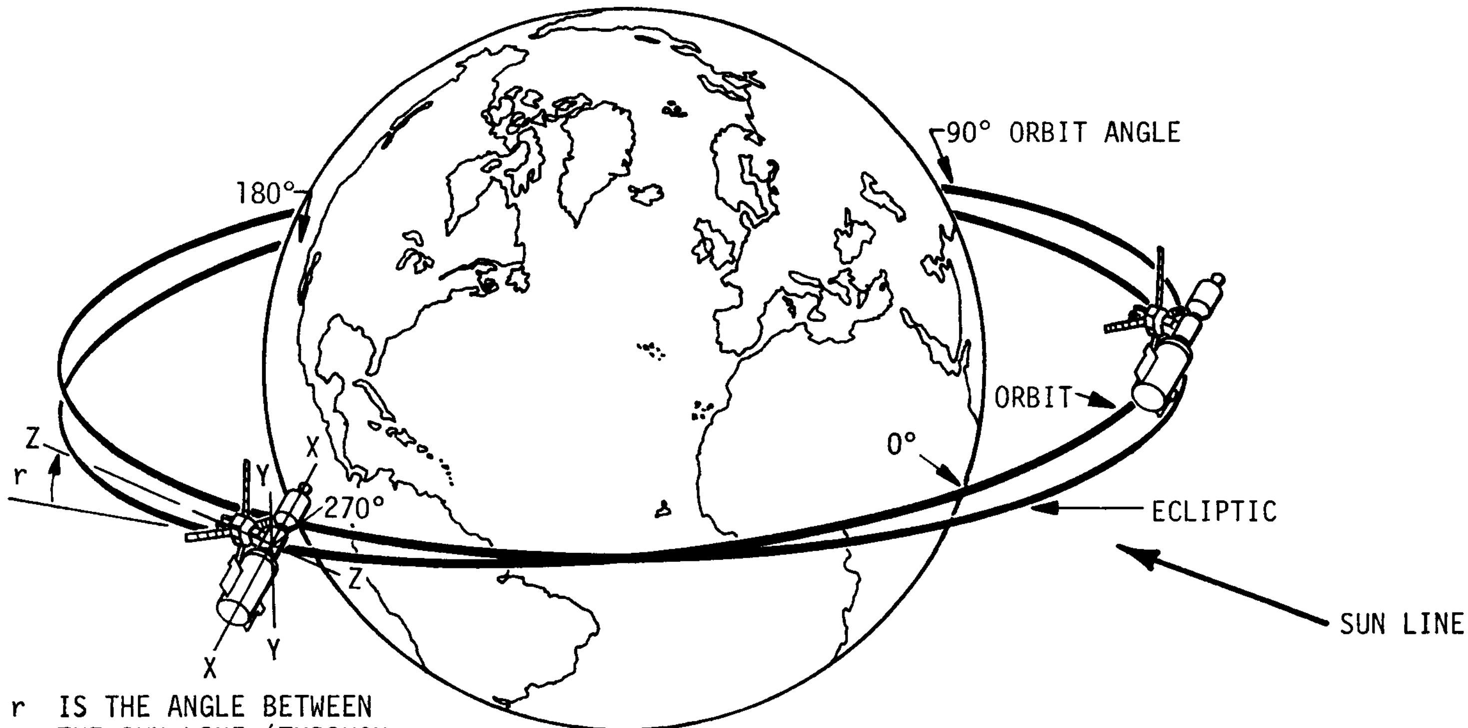
D. Attitude Control

The purpose of the attitude control system is to hold the attitude of the cluster (Figure 23) with the X axis in the orbital plane, and to hold the solar panels perpendicular to the solar vector.

Two systems were considered in this study to provide attitude control of the cluster for this mission.

It was found in the Appendix,Paragraph E that the estimated reaction control system (RCS) propellant requirement would be excessive for a 56-day mission if only the ATM RCS were used to provide the required attitude control. Therefore, the use of control moment gyros (CMGs) as developed for the ATM-A program is recommended.

1. Control Moment Gyros. A CMG system will be used to control the cluster attitude in the orientation (Figure 23) under consideration for this payload. The CMG system is a momentum exchange control



r IS THE ANGLE BETWEEN THE SUN LINE (THROUGH THE Z AXIS) AND THE ORBITAL PLANE.

FIGURE 23. ATM-B IN EARTH ORBIT

system. The momentum exchange devices are three orthogonally-mounted, double-gimbaled CMGs. The CMG system supplies the encounter torque about three orthogonal vehicle axes to react against cyclic disturbance torques as caused by gravity gradient and aerodynamic drag. The CMG's are physically mounted to the structure of the LM/rack, and can hold the cluster attitude about the three axes with an error of less than 10 minutes.

The gravity gradient and aerodynamic torques on the cluster are cyclic about the Y and Z axes, but not about the X axis, when the longitudinal principal axis is constrained to lie in the orbital plane. The CMG control system can compensate for disturbance torques indefinitely only as long as the torques are purely cyclic. However, the CMG control system requires periodic momentum desaturation since the disturbance torques being compensated have a bias level. Momentum desaturation is accomplished by using the RCS system which requires approximately 10 seconds every third orbit. The total impulse about the X, Y, and Z axes of 1 300 lb-sec is required for momentum desaturation for a 28-day mission analyzed in a previous report (Ref. 9). For this 56-day ATM-B mission, assuming the reorientations would take place mostly about the X and Y axes, propellant consumption by the RCS thrusters is estimated at approximately 50 pounds.

The weight statement for ATM-A, shown in Tables 3 and 4, contains the propellant required for rendezvous, docking, and momentum desaturation.

Gross cluster orientations in pitch and yaw will be referenced to a Sun line established by the Sun sensor during the daylight portion of the orbit. The cluster roll attitude will be referenced to a star tracker. The attitude control system will be provided with three body-mounted, single-degree-of-freedom, rate integrating gyros for attitude reference during occultations of the Sun sensor or star tracker during the night portion of the orbit.

2. Calculations to Determine RCS Propellant Requirements. A study was made to determine the amount of RCS propellant required on the mission if CMG's were not used. The calculated quantity of LM/RCS propellants required is based on the quantity for the thruster system to produce an amount of momentum equal to that produced by the continuously acting gravity gradient and aerodynamic torques.

The attitude disturbance impulses arising from the effects of gravity gradient and aerodynamic torques during each orbit, with the X axis in the orbital plane and the cluster Z axis along the line of sight from the cluster to the Sun, are found to be:

- 4 910 ft-lb-sec impulse about the Z axis (peak value of cyclic impulse)
- 4 210 ft-lb-sec impulse about the Y axis (peak value of cyclic impulse)
- 350 ft-lb-sec impulse about the X axis.

The total propellant for the LM attitude thrusters required to balance the torque disturbances due to gravity gradient and aerodynamic effects is 6 870 pounds. This value increased by 15 percent safety factor is 7 900 pounds for a 56-day mission (see Appendix, Paragraph E).

3. Estimation of Required Propellants Quantity for ATM-B, Based on Completely Simulated ATM-A. The propellant requirements for the 56-day ATM-B mission are calculated to be 8 911 pounds for disturbance torques about the Y and Z axes (see Appendix, Paragraph E) based upon a 28-day ATM mission analysis performed in Reference 9. That analysis indicates a requirement for a 225 000 lb-sec impulse for control of all attitude disturbances about the X, Y, and Z axes based on a complete digital computer simulation of the cluster and attitude control system dynamics.

E. Experiment Pointing Control

The experiment pointing control subsystems (EPCS) will be utilized to provide the desired maneuverability, pointing accuracy and stability of the individual experiment platforms.

In consideration of the varied requirements and frequent reorientation of the viewing angle for the eight experiments proposed for this payload, it appears feasible to group the experiments into three scientific groups and utilize a separate mounting platform with independent EPCS for each platform (Figure 14). A brief description of each platform and its proposed EPCS to meet the requirements of all eight experiments without reorientation of the cluster is shown in the following paragraphs.

1. UV Platform. The UV platform (Figure 17) and its pointing control system will provide the experiment pointing accuracy and stability for three of the eight proposed experiments. Because of the required pointing accuracy and stability of the three experiments, (1) Ultraviolet Photography Survey (Tifft), (2) Far Ultraviolet Spectrograph (Carruthers), and (3) Far Ultraviolet Spectrograph (Morton), it will be necessary to use a stabilized platform. The stabilized platform considered is currently under development by the Astrionics Laboratory of MSFC, and most of the design details have been completed. The UV platform will provide the following functions:

- Inertial space fixed experiment payload independent of angular cluster motion
- Manual and automatic sequence of operation, including gimbal positioning capability by astronaut command
- Instantaneous and continuous display of experiment package orientation to within ±0.01 degree (with respect to cluster attitude)
- Sky scans in 4-degree increments
- Gimbal limit signal to interlock camera shutter mechanism
- Means for astronaut viewing of the same source as the camera is viewing
- Stability of ±0.01 degree for 20 minutes (pitch, yaw and roll axes).

2. X-ray Platform. The X-ray platform and its pointing control subsystem will provide the pointing control for two of the eight experiments proposed for this payload. These two experiments are the X-ray Sky Survey Panels (Friedman) and the Modulated Collimator X-ray (Gursky). This subsystem will consist of a mounting platform for the experiments, which will be fixed to a telescopic deployment mechanism that is attached to the rack (Figure 14).

The CMG system will provide the attitude control and stabilization for these experiments. Additional control and readout features of the X-ray platform will provide the following:

- Manual and automatic incrementing of the X-ray sky survey panels position
- Manual and automatic scan mode to scan the sky at a rate of 6 deg/min for 360 degrees
- Readout of experiment orientation with respect to spacecraft attitude
- Automatic and manual controls to extend the telescopic deployment mechanism to its optimum position.

3. Gamma-ray Platform. The gamma-ray platform and its EPCS will provide the pointing control for three of the eight experiments proposed for this payload. These three experiments are the Gamma-ray and X-ray Spectroscopy (Peterson), the Low-energy Gamma-ray Sky Survey (Frost), and the Spark Chamber (Frye) or Digitized Spark Chamber (Fichtel). This EPCS will consist of a mounting platform for the experiments which will be fixed to a swing arm deployment mechanism that will have controlled movement in three axes (Figure 14). Each axis will have transducers for attitude readout and will be controlled by precision torquers or stepping solenoids.

The CMG system will provide stabilization for these experiments. Additional control and readout features of the gamma-ray platform will provide the following:

- Manual or automatic pointing toward a selected source
- Attitude readout on all three axes within ±10 arc minutes with respect to spacecraft attitude

- Manual and automatic sky scanning for periods of up to 2 hours with controlled scan rates

- Manual means for astronaut to verify pointing alignment of experiments

- Stability of ± 10 arc minutes (pitch, yaw, and roll).

APPENDIX. SUPPORTING INFORMATION

A. Experiment Descriptions

1. Ultraviolet Photography Survey (Tifft). The camera system consists of twin 6-inch ultraviolet cameras for obtaining high-quality images of star fields in selected portions of the ultraviolet spectrum, together with a small wide-angle 16-millimeter camera for backup identification and analysis of the field of view in the visible region of the spectrum. The three cameras with associated electronics are mounted on a stable platform which holds the look angle of the cameras steady with respect to inertial space during an exposure sequence.

The ultraviolet cameras are used to conduct a photographic survey of the sky. Their field of view is approximately 5 degrees and their sensitivity extends from 1800 to 3000 Å. Stellar images are returned on 35-mm ultraviolet sensitized film. Each cylindrically shaped camera is 21 inches in length and 16 inches in diameter. The entire experiment weighs 179 pounds. Figure A-1 shows a cutaway view of the ultraviolet camera designed by the University of Arizona.

2. Far Ultraviolet Spectrograph (Carruthers). The spectrograph is a Schmidt-type electronic image converter with objective gratings. The sensitive region of the spectrum is from 1230 to 1800 Å, and data are recorded on a nuclear emulsion film. Housekeeping functions will be telemetered. Although the spectrograph has an irregular shape, it can be contained in a 25 1/4-by 17 1/4-by 9 1/4-inch volume with a total weight of 62.2 pounds. The spectrograph is mounted on the above-mentioned instrumentation platform which allows for ±100 degrees rotation about an axis that is perpendicular to the viewing direction. It also allows for a pitch and roll of 20 degrees about the observation axis. The spectrograph as shown in Figure A-2 has a field of view of 17 degrees. The experiment was designed by the Naval Research Laboratory.

3. Modulated Collimator X-ray (Gursky). The detector, designed by American Science and Engineering Inc. and as shown in Figure A-3, is surrounded on the sides and back by an anticoincidence detector and views objects through slat and grid-type collimators. The detectors and collimators form a 32-by 28-by 22-inch unit. In addition two smaller units, an aspect detector and an electronic package, are required for the experiment. The entire package weighs 90 pounds. The grid-type collimators

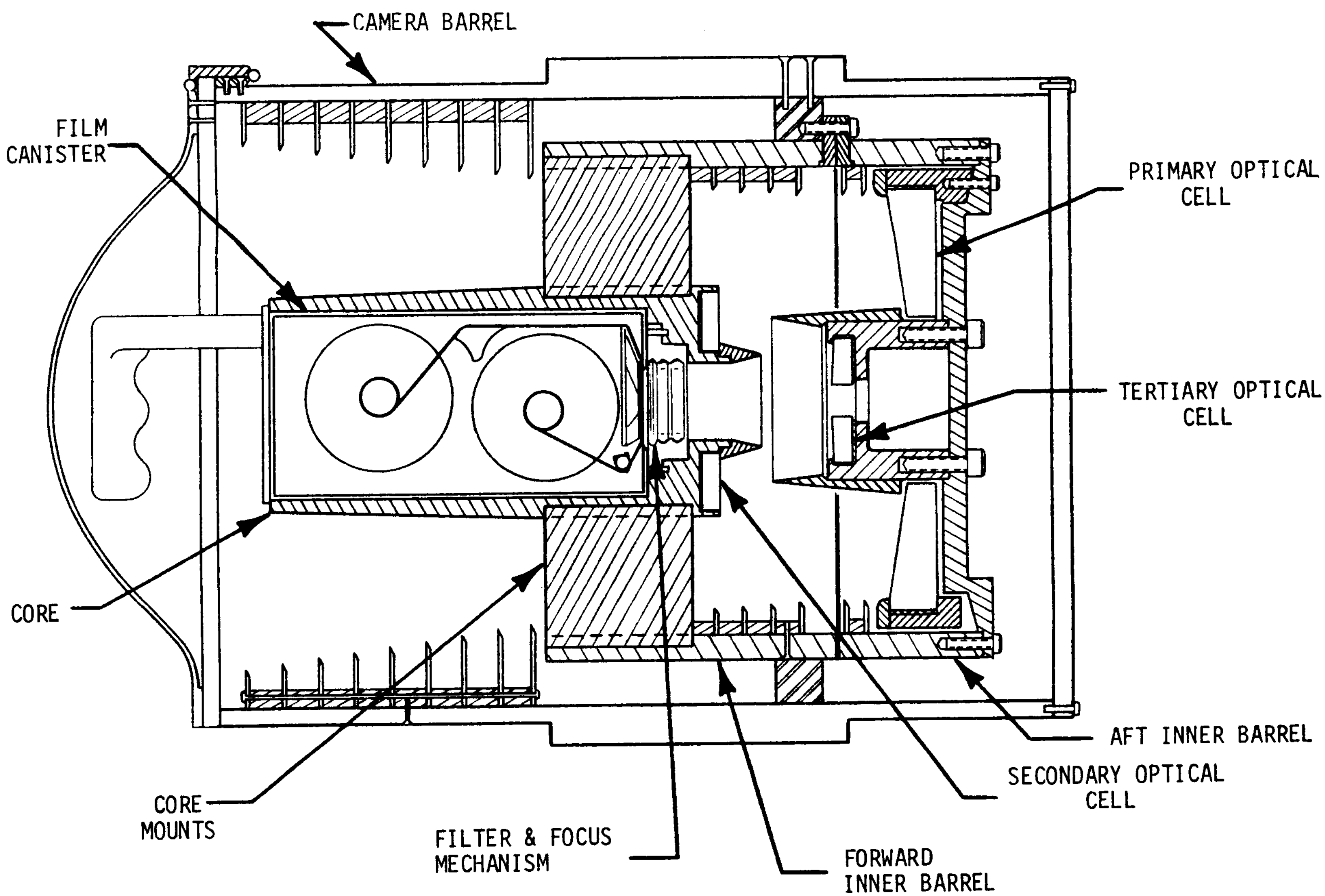


FIGURE A-1. CUTAWAY VIEW OF ULTRAVIOLET CAMERA (TIFFT)

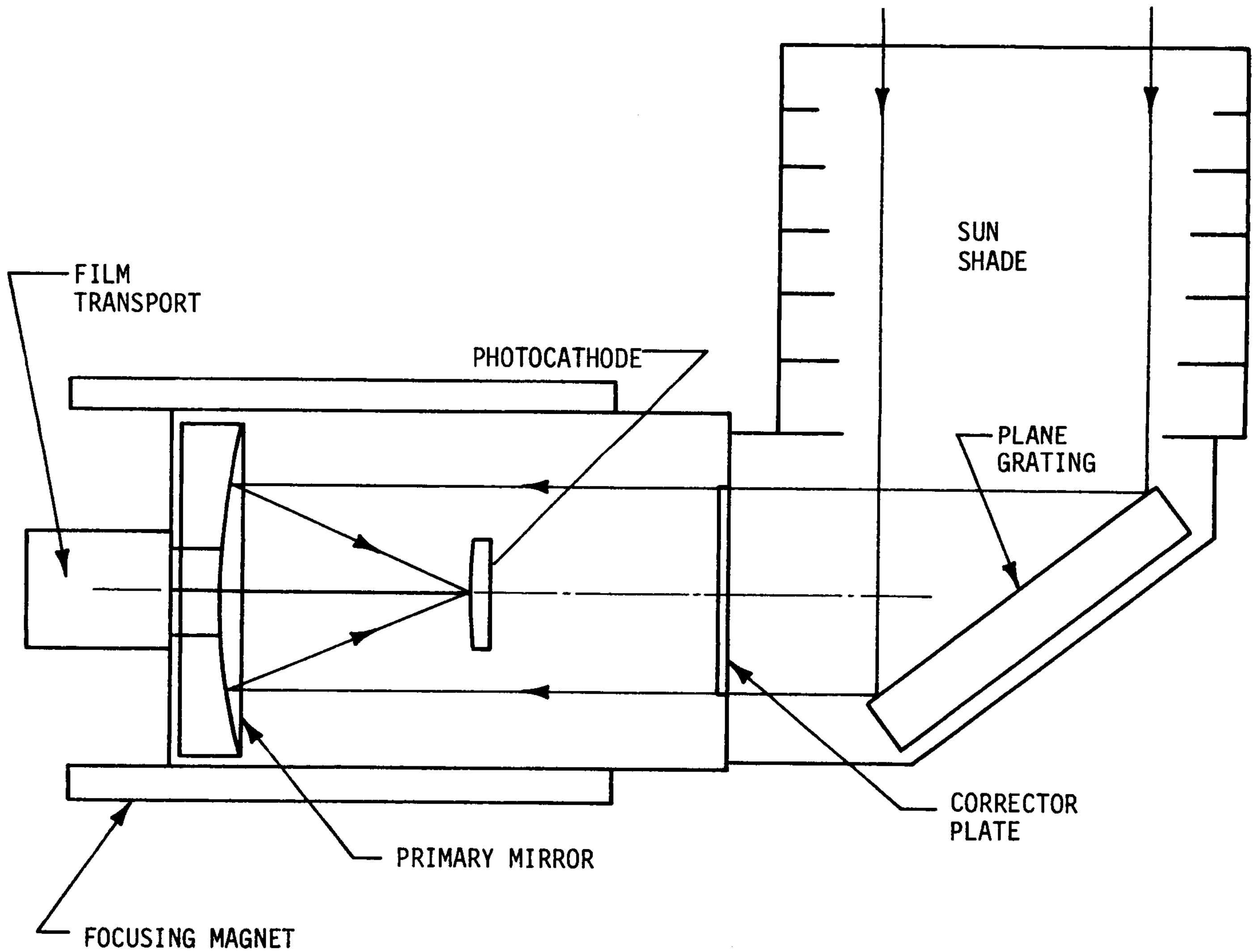


FIGURE A-2 SCHMIDT IMAGE CONVERTER STELLAR SPECTROGRAPH (CARRUTHERS)

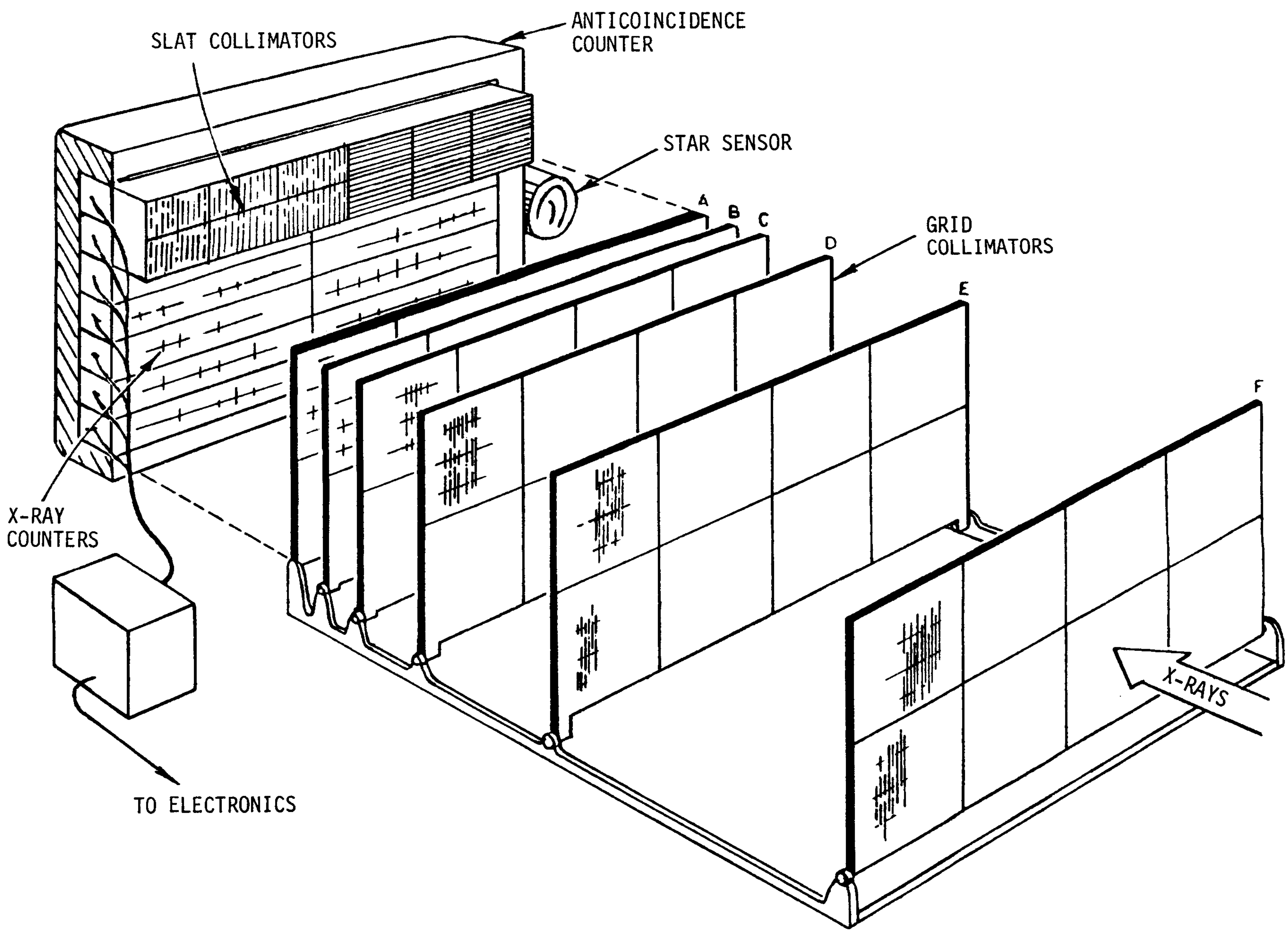


FIGURE A-3. MODULATED COLLIMATOR X-RAY DETECTOR (GURSKY) have a field of view of 40 minutes; however, resolution may be varied in six steps from 38 seconds to 40 minutes. The slat collimators have a fixed field of view of 4 by 20 degrees. The X-ray energy range of the detector is 0.25 to 25 keV. Data are recorded on tape and telemetered to Earth.

4. Low-energy Gamma-ray Sky Survey (Frost). A cesium-iodide crystal serves as the basic detector. Another cesium-iodide crystal encloses the first crystal and serves as the anticoincident system.

Photomultipliers view the reactions of the crystals with photons and charged particles. The logic circuitry then permits the gamma-ray induced pulses into the proper channel of a 128-channel pulse-height analyzer. Figure A-4 is a sketch of the detector unit. The apparatus, designed and developed by Goddard Space Flight Center, has dimensions of 22 by 22 by 18.5 inches including phototubes and a weight of 200 pounds (including electronics). The sensitivity of the spectrometer extends over the 15- to 360-keV range, and the acceptance angle is ± 2 degrees. Recorded data are telemetered to Earth.

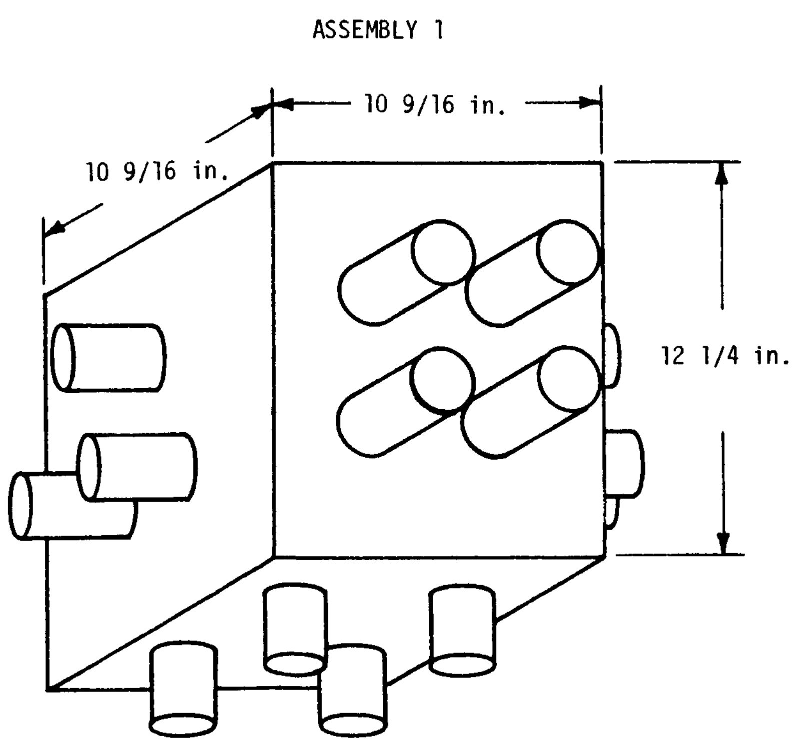


FIGURE A-4. DETECTOR UNIT FOR LOW-ENERGY GAMMA RAY (FROST)

5. <u>Digitized Spark Chamber (Fichtel)</u>. This spark chamber, designed by Goddard Space Flight Center and as shown in Figure A-5, is cylindrical in shape and has dimensions of 28 inches in diameter by 30 inches in length and weighs 195 pounds. The chamber consists of a thick plastic scintillator serving as an anticoincidence dome, a pair of spark chambers, and a Cerenkov counter and central scintillator for triggering. Charged particles have little chance of being recorded because of the anticoincidence system.

A gamma ray (with energy greater than 30 MeV) striking a plate will produce an electron-positron pair. The relativistic electrons will then trigger the Cerenkov counter and central plastic; and if there is not a corresponding signal from the anticoincidence system, a high voltage is applied. The spark is formed between wire grids. Each wire threads a magnetic core which is normally in a "reset" mode. Spark current in a wire sets the core and the data consist of the addresses of all the cores that have been set. The sparks' directions allow determination of the energy and direction of the original gamma ray. The field of view is ± 45 degrees.

6. <u>Gamma-ray and X-ray Spectroscopy (Peterson)</u>. The X-ray and gamma-ray detector configurations, as designed by the University of California, are shown schematically in Figure A-6. The X-ray proportional counter will have a thin window supported by a grid and will be filled with a suitable gas to a pressure of 1 atmosphere. A gas reservoir with at least ten times the volume of the counter will be connected to the counter by means of a capillary tube. The reservoir will reduce the effect of pressure changes on the gas gain. The material which surrounds and collimates the X-ray detector will be a plastic scintillator.

The inner crystal of the anticoincidence gamma-ray telescope will be a NaI (Tl). The active shield will probably be CsI (Tl) which has mechanical properties superior to NaI (Tl). Ruggedized photomultiplier tubes of appropriate diameters are available for the system and the active X-ray shield.

Both detectors are cylindrical in shape. The gamma-ray spectrometer is 25.5 inches in length and 9.5 inches in diameter, and the X-ray detector is 11.2 inches in length and 6 inches in diameter. All equipment will weigh approximately 235 pounds.

The sensitivity ranges are 1 to 30 keV and 0.3 to 10 MeV. Data are recorded on tape and telemetered to Earth. Both detectors are aligned to view in the same direction.

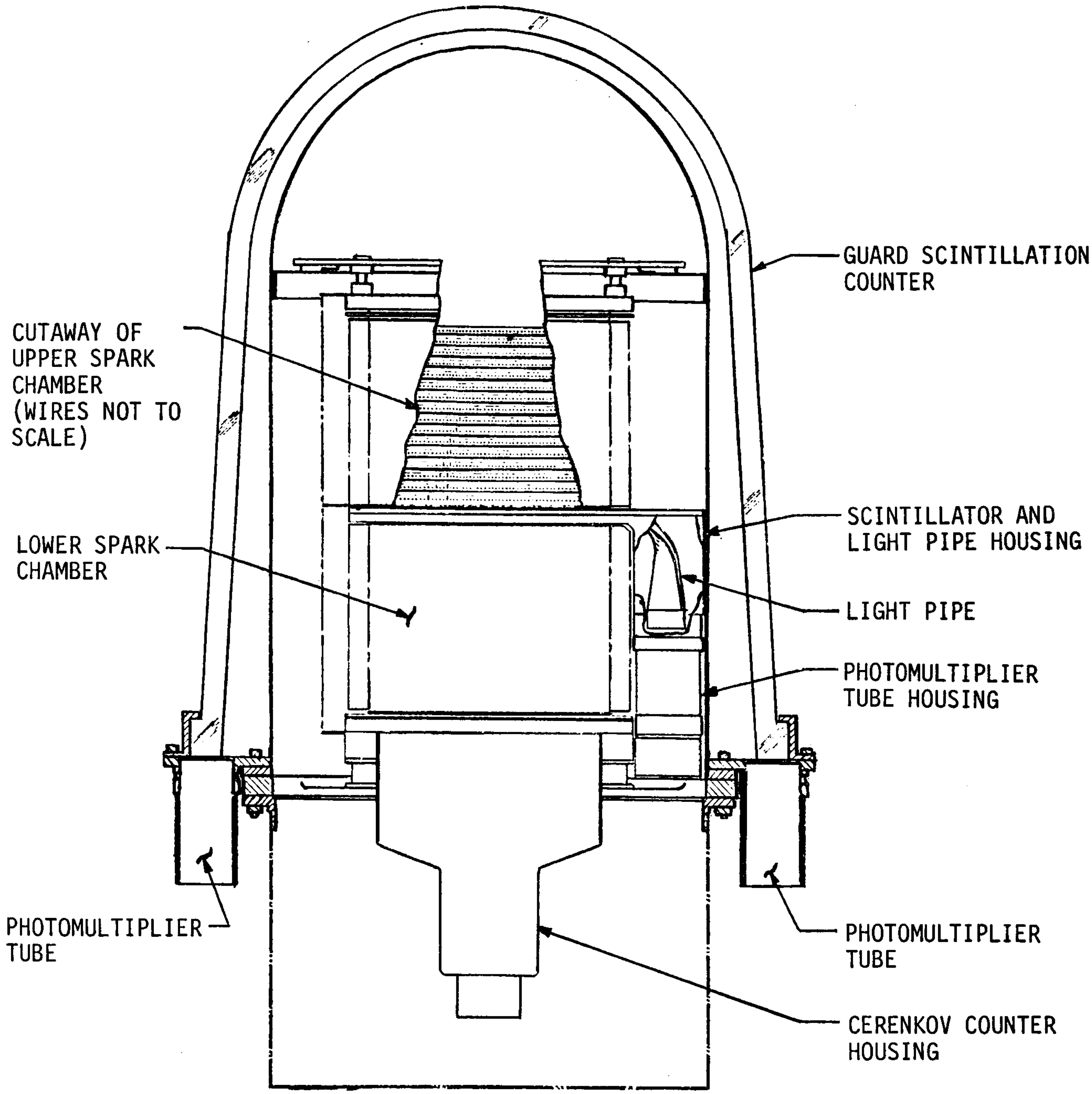


FIGURE A-5. DIGITIZED SPARK CHAMBER (FICHTEL)

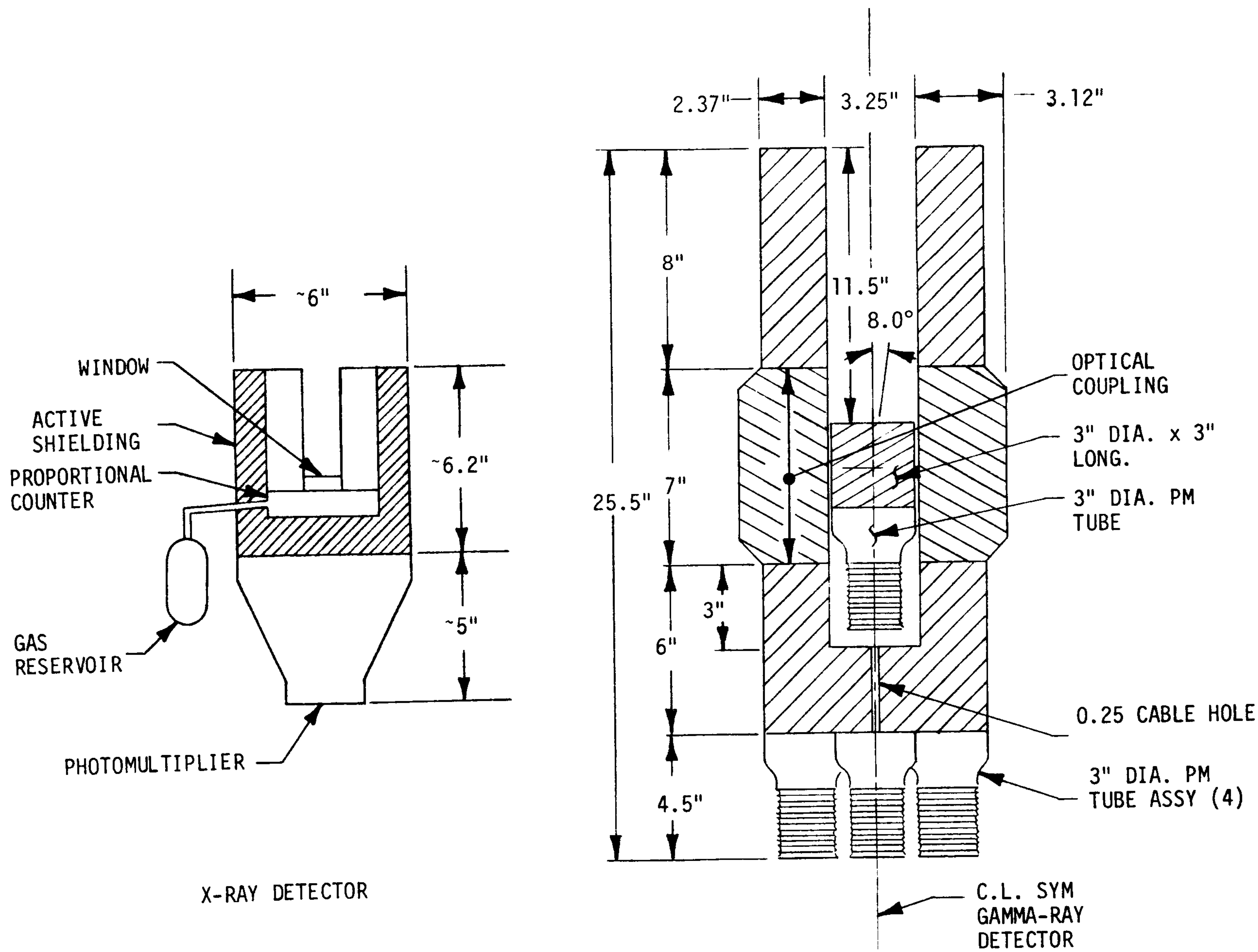


FIGURE A-6. GAMMA-RAY AND X-RAY DETECTOR SPECTROSCOPY (PETERSON)

7. X-ray Sky Survey Panels (Friedman). The detection apparatus, designed by the Naval Research Laboratory, is basically 14 proportional counter modules (one of which is shown in Figure A-7). Each of the counters is approximately 24 inches square, weighs 200 pounds, and consists of a collimator which lies above the structural egg crate and honeycomb window support. Below the window support is the thin window and proportional counter followed by the anticoincidence proportional counter. A 2500-volt power supply, an amplifier, a pulse-height analyzer, a gas system regulator and valve, and a prescaler will be mounted in the back of each counter. The modules can be grouped in two wings or panels. Each wing contains two panel mixers, a PM aspect detector, two voltage regulators, two wing mixers, and a three-axis magnetometer.

A counter having identical geometry is located behind the data collecting counter. Its purpose is to detect high-energy electromagnetic radiation. This counter will be used with the anticoincidence circuitry to reduce the background counting rate.

The collimators permit a ± 1 by ± 4-degree field of view and the sensitive energy range is 0.5 to 40 keV.

8. Far Ultraviolet Spectrograph (Morton). The spectrograph, designed by Princeton University and as shown in Figure A-8, is an all-reflective instrument with an objective grating and LiF coated optics mounted on a platform. The spectral range is from 900 to 1800 Å with dispersion spectra of O, B, and A stars down to the sixth magnitude. Recording is on photographic film with a resolution of 0.5 Å. A 35-millimeter motorized Nikon Camera will also be utilized to help sort out overlapping fields. A small ion chamber with volume of a few cubic inches weighing 0.5 pound can also be mounted on the platform to monitor the local Lyman alpha flux.

The spectrograph weighs approximately 62 pounds which includes 35 pounds of shielding. A 6-degree field of view is afforded, and exposure times are from 10 to 20 minutes at the rate of 150 to 225 exposures per mission. Approximately 56 to 75 film planchettes can be carried per film cassette.

9. Spark Chamber (Frye). The spark chamber consists of a plastic scintillator serving as an anticoincidence detector, a series of plates with the gas-filled chamber, a Cerenkov coincidence detector, and a photographic system.

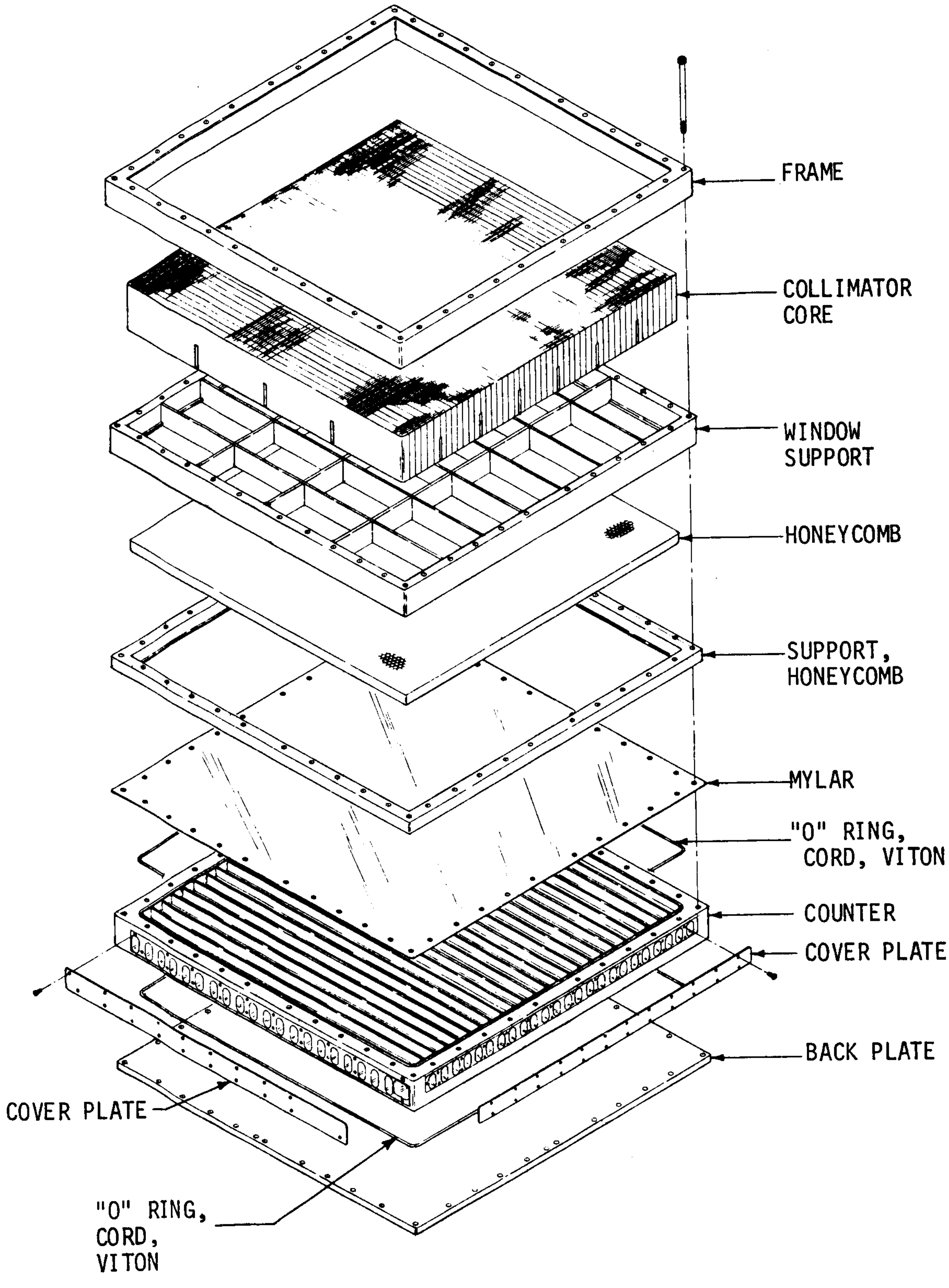


FIGURE A-7. X-RAY COUNTER (FRIEDMAN) ONE MODULE SHOWN

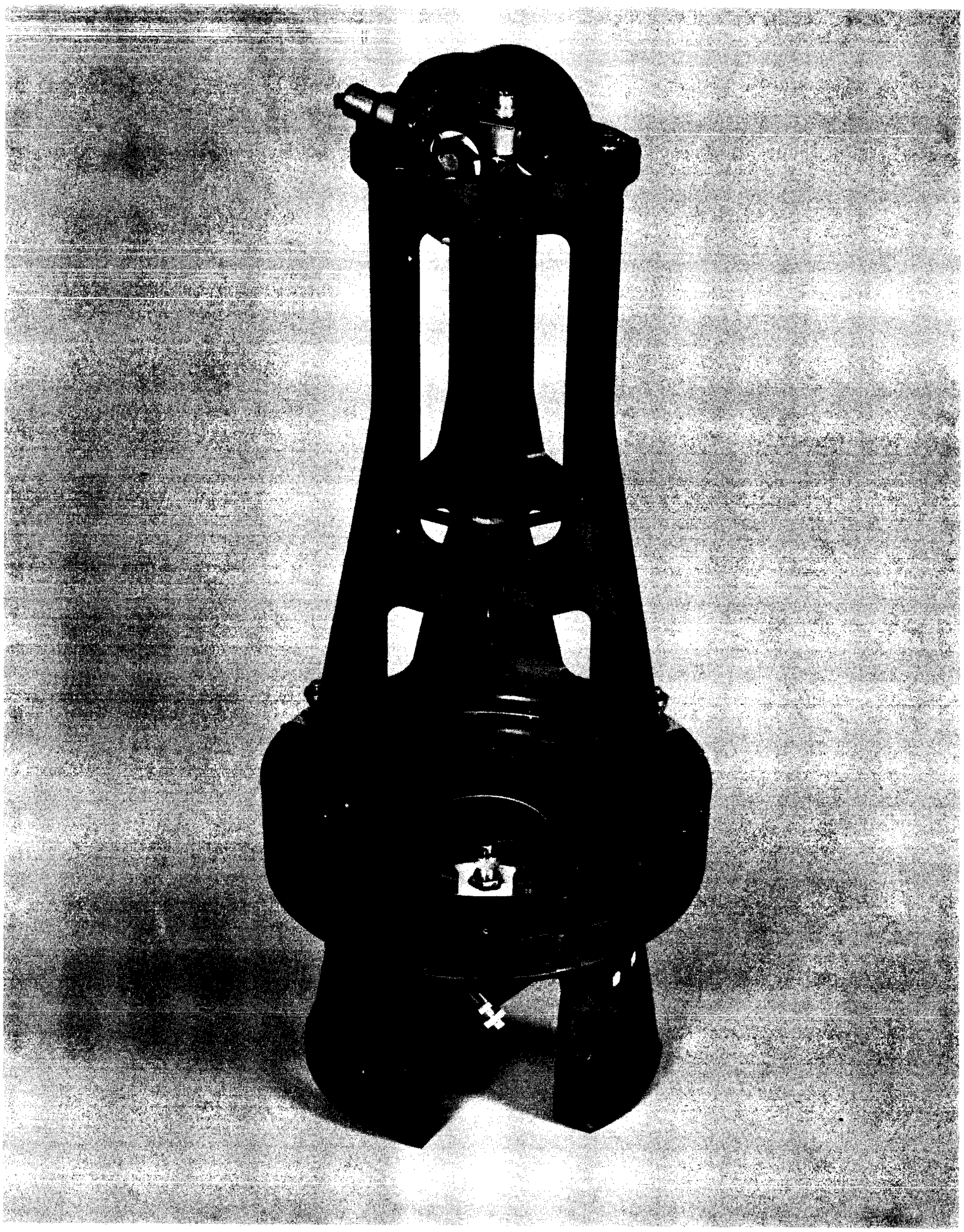


FIGURE A-8. SPECTROGRAPH WITH ALL-REFLECTIVE OPTICS (MORTON)

The Cerenkov counter detects the passage of charged particles through the spark chamber (Figure A-9). A check is made using the anticoincidence system to determine if the charged particles resulted from gamma-rays hitting the plates. If so, high voltage is applied and photographs are taken of sparks which mark the trail of the charged particles through the gas-filled detector. The directional flux of gamma-rays from various regions of the sky will be measured. The energy range under consideration is greater than 30 MeV.

The system will be pressurized and enclosed by a 40-inch diameter, 60-inch long cylinder. The weight will be approximately 250 pounds and the power consumption will average 50 watts. The experiment design and development is being done by Case Institute of Technology.

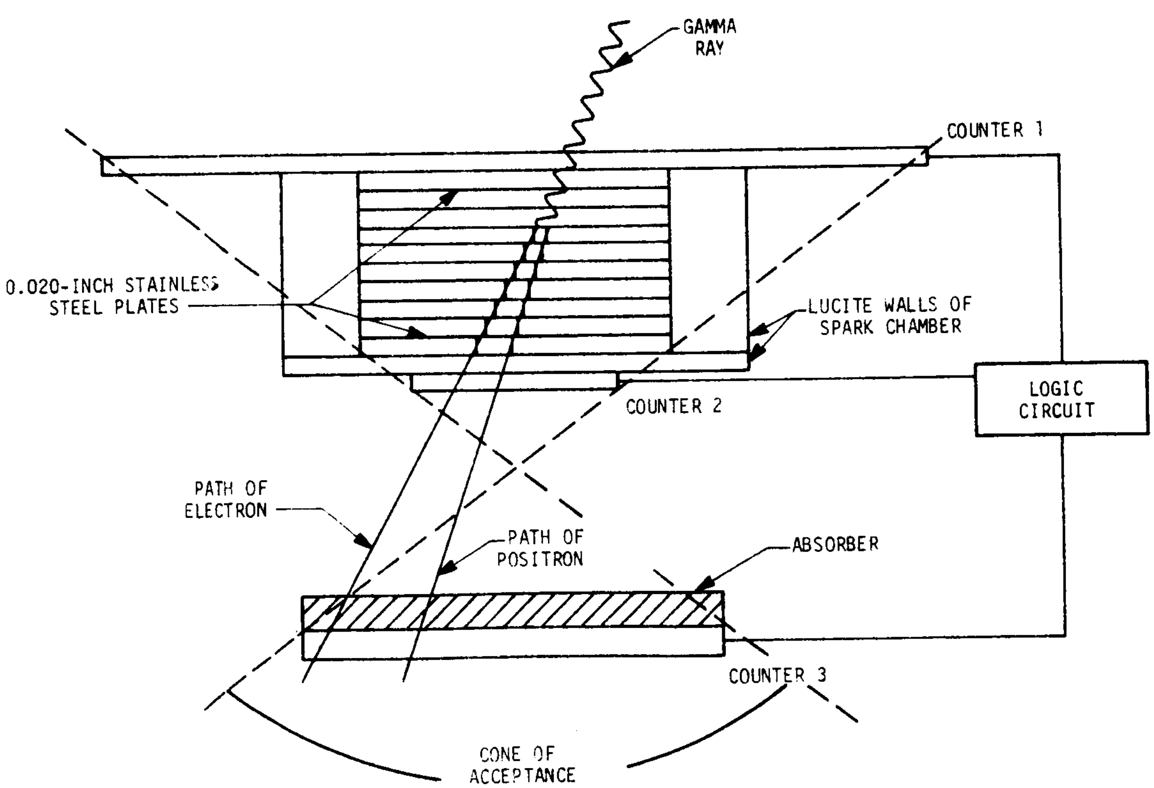


FIGURE A-9. SPARK CHAMBER FUNCTIONAL DIAGRAM (FRYE)

10. Summary of Experiment Requirements

A summary of ATM-B experiment requirements is shown as follows:

Experiment and Investigator	Component	Weight (lb)	Power (watt) Avg.	Power (watt) Max.	Dimensions (in.)	Temperature Operation	Temperature Standby	Energy Range	Resolution	Maximum Telemetry	Field of View	Viewing Time Per Source	Pointing Accuracy	Purpose	Notes
Ultraviolet Photography Survey (Tifft-University Arizona)	Two 6-in. Cameras 16 mm Camera Electronics Misc. TOTAL	70 (each) 4 15 20 179	Small 0 20 - 20	44 0 20 - 64	21 long 16 dia. (each)	-20° to 40°C Film 0° to 30°C	-50° to 60° Film Below 30°C	1800 to 3000 Å or 4 to 6.7 eV		160 bits/sample 4 samples/hr (HSKP)	4.5° by 6.4°	20 min.	± 0.2° and 36 Arc Sec for 20 Min	Photographic records of star fields in continuum and emission line records	Film retrieval every 5 days. Different modes require varying amounts of astronaut participation. Prefer night portion of orbit for viewing.
Far-Ultraviolet Spectrograph (Carruthers-NRL)	Schmidt Spect. Misc. TOTAL	49.7 12.5 62.2	2	50	25¼ x 17¼ x 9¼	-20° to 40°C	-20° to 40°C	1230 to 1800 Å	~0.5 (Energy)	10 samples/hr (HSKP)	~17°	18 min.	± 0.25° and 60 Arc Sec for 10 Min.	Spectral and photometric data on stars, interstellar medium and extragalactic objects. Conduct sky survey.	Film retrieval every 5 days. Prefer dark portion of orbit for observations.
Modulated Collimator X-Ray (Gursky-AS&E)	Detector Electronics Control-Display TOTAL	55 30 5 90	1 5 1 7	2 5 4 11	32 x 28 x 22 12 x 12 x 6 8 x 6 x 4	-20° to 50°C	-50° to 60°C	0.25 to 25 keV	5 arc sec (Spatial)	40 samples/sec 2 kbits/sec	± 10° by ± 10°	Up to 30 min. and 2° to 3°/min Scan	± 0.5°	Obtain position, spectra and dimensions of sources, conduct search for new sources.	
Low Energy Gamma Ray Sky Survey (Frost-Goddard SFC)	Detector Electronics TOTAL	157.5 42.5 200	18	18	22 x 22 x 18.5 flexible (1 ft³)	-20° to 35°C (prefer at 10°C)	-30° to 45°C	12 to 360 keV		1 kbit/sec 1 sample/sec	± 2°	1 to 2 hrs. and 1° to 1.5°/hr Scan	± 0.5°	Measure flux, spectrum and arrival direction. Conduct a general sky survey.	
Digitized Spark Chambers (Fichtel-Goddard SFC)	Single Unit	195	7	9	28 dia. 30 long	5° to 40°C	-5° to 50°C	Above 30 MeV	2° to 5° (Spatial) 50% (Energy)	800 bits/sec 1 kbit/sample	± 45°	Up to two weeks	± 0.5°	Obtain flux and arrival directions of high energy Gamma-rays.	Mount the detectors so the long axis is parallel to the lift-off direction.
Gamma Ray and X-Ray Spectroscopy (Peterson-Univ. Cal.)	Electronics Detector Gamma-ray Detector X-ray Detector TOTAL	20 190 25 235	10 0.1 10.1	10 0.1 10.1	Gamma-Ray Detector 25.5 long x 9.5 dia. X-Ray Detector 12 long x 6 dia.	0° to 60°C	-20° to 60°C	Gamma-Ray Detector 1-30 keV X-Ray Detector 0.3-10 keV		1 kbit/sec	± 5°	10 min. (X-ray) ~2 hours (Gamma-ray)	± 0.5°	Measure energy spectra of X-ray and Gamma-ray emissions from cosmic sources.	Two detector units are included. Voice communication with ground is desirable.
X-Ray Sky Survey Panels (Friedman-NRL)	Detector Modules Electronics Storage Bottle(s) TOTAL	50 lb/ft² 60 180 ~3040	~130	~130	24 x 24 x 12 (each)	-18° to 60°C		0.7 to 40 keV	1° to 2° (Spatial)	122 words 10 bits/word 1 sample/sec	± 1° by ± 4°	Scan rate 4° to 6°/min	± 0.5°	Map and obtain photometric data on X-ray sources. Obtain intensity and spectral distribution of the background.	Fourteen identical modules will be used in the array. P-10 gas will be used in each module and a supply tank(s) will be necessary.
Far Ultraviolet Spectrograph (Morton-Princeton University)	All Reflective Spectrograph	62 including 35 for shielding	0.5	56	12 dia x 29 long Conical Shaped	Vary less than ±25°C		900 to 1800 Å	0.5 to 5 Å	Housekeeping data only	±6°	10-20 min.	Not Specified 60 Arc Sec for 10 Min.	Far ultraviolet spectra of stars down to 6th magnitude	EVA for film cassette changes at 14-day intervals. 3 cassettes for return.
Spark Chamber (Frye-Case Institute of Technology)		250	50	100	60 long 40 dia.	0° to 45°C	-10° to 45°C	Above 30 MeV		10 kbits/sample 1 sample/day	±25°	Min 20 hr Max. 2 days	± 1.0°		Measure flux and spectrum of high-energy gamma-ray sources.

B. Structural

The ATM-A rack primary structure is an indeterminate structural system. IBM has developed a programming system for solving problems concerning this type of structure on the 1130 computer. The title of the program is Structural Engineering System Solver (STRESS). The 1130 STRESS is composed of two parts: a language describing the problem and a processor or computer program that interprets this language and produces the desired answers.

The user describes a problem with the 1130 STRESS language by writing a number of statements specifying the type and size of the structure, the physical dimensions, the loads, and the output desired. The 1130 STRESS language is easily understood, and the terms employed in describing a problem are essentially the same as those for general engineering usage.

In the analysis of framed structures, 1130 STRESS deals with forces, reactions, moments, displacements, and distortions. To correlate these quantities, a common reference system must be defined. The 1130 STRESS uses a right-handed, orthogonal Cartesian coordinate system to describe all components of force and displacement vectors (see Figure A-10). Furthermore, in the entering of input data and interpretation of output results from 1130 STRESS, distinction must be made between the global (joint) coordinate system and the local (member) coordinate system.

The global coordinate system is an arbitrarily chosen system related to the entire structure. It is generally chosen so that the directions of the axes coincide with the major dimensions of the structure or the axes of symmetry, if the structure is symmetrical. The origin of the system may be located at any arbitrary point for convenience. All joint data are described in terms of coordinates with respect to the origin of the global coordinate system. All computed joint displacements, forces, and reactions are similarly given in the same system.

The local coordinate system is associated with each member. The local X axis coincides with the axis of the member, and its direction is determined from start to end of the member, as specified in the input data. The Y and Z axes coincide with the other two principal axes of the member. The coordinates of the end points of a member determine the position of the member in space.

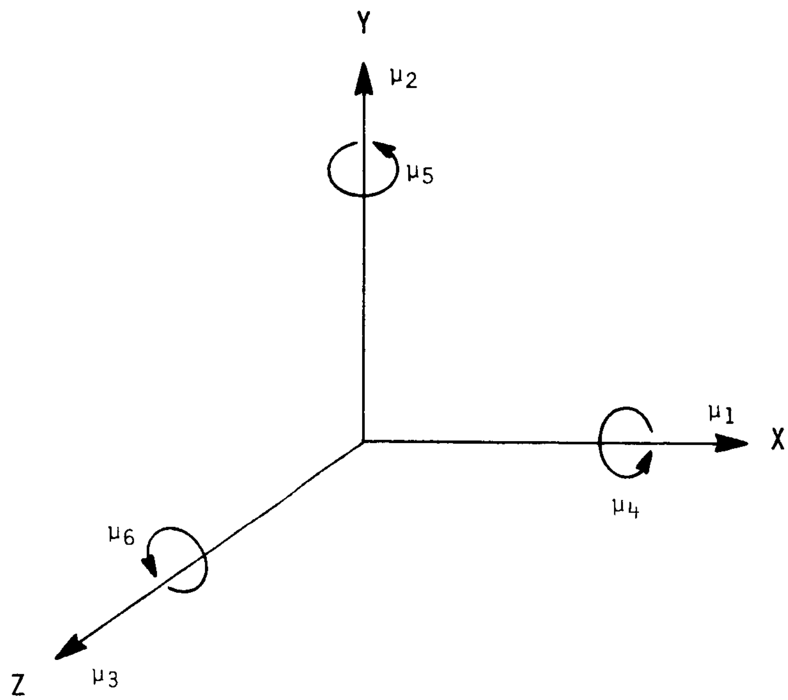
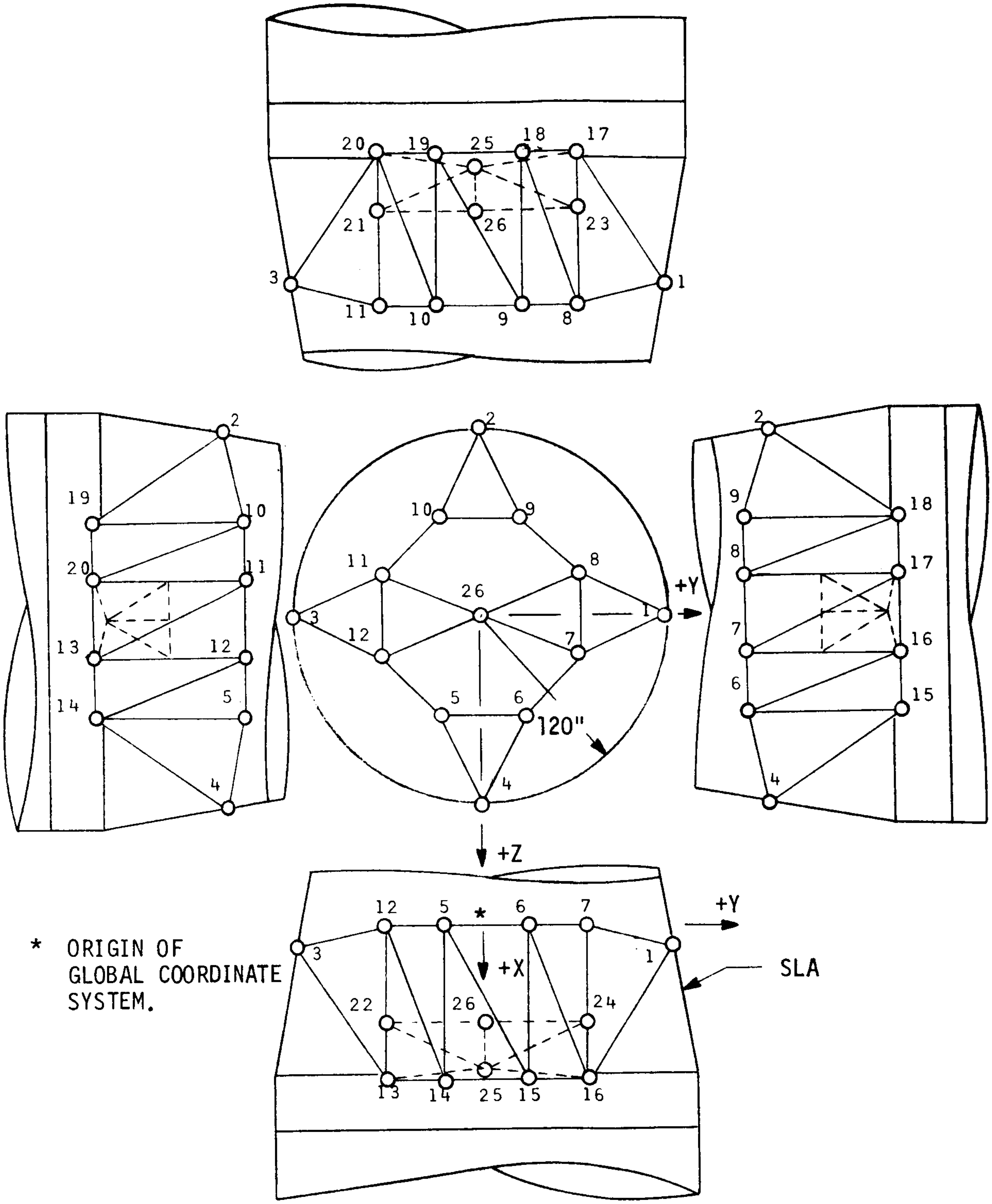


FIGURE A-10. CARTESIAN COORDINATE SYSTEM

In the analysis of structures by 1130 STRESS, it is assumed that the relationship between all forces or displacement vector components of a member or a joint is governed by identical continuity and equilibrium equations. In many cases, there may be local deviations from this pattern. For instance, the use of hinges or rollers at supports will make some force components equal to zero. To avoid any ambiguity in the meaning of such terms as hinges or rollers, the 1130 STRESS language introduces the word "releases" to specify zero force components. Two types of releases are implemented in the 1130 STRESS: joint releases and member releases.

The four support joints for the ATM rack structure which are located at the SLA attach points were released so that the joints are not fixed against rotation about the X, Y, and Z global coordinate axes. These joints are numbered 1, 2, 3, and 4 in Figure A-11.

The primary rack structure was analyzed for structural integrity by considering load data generated by MSFC. The critical loading



* ORIGIN OF GLOBAL COORDINATE SYSTEM.

FIGURE A-11. MATHEMATICAL MODEL (RACK PRIMARY STRUCTURE) condition for the rack was assumed to be that of lift-off. At lift-off severe dynamic loading in both the lateral and longitudinal directions is encountered. Since the lateral load factor can occur in any direction, two conditions were considered as indicated in Table A-1. For the first condition the lateral load factor was assumed to act in the Y-direction (Figure A-11) and for the second condition it was assumed to act in the Z direction.

The load factors were applied at the centers of mass for the major payload items that are supported by the rack. These items are the LM ascent stage, the control moment gyros, the X-ray platform, solar panels, the gamma-ray platform, and the ultraviolet platform. These concentrated loads were, in turn, resolved into joint loads at specific points on the rack. All applied joint loads are eventually reacted at the SLA attach points for external equilibrium. The magnitude and direction of the applied forces and moments that were applied at the joints are shown in Table A-1. The sign convention for these applied forces and moments is consistent with the global coordinate system shown in Figures A-10 and A-11.

The results of this analysis indicate that the primary rack structure associated with the ATM-A baseline configuration is more than adequate for the revised payload. If permissible, the existing rack could be optimized and a weight saving realized.

The mathematical model shown in Figure A-11 deviates slightly from the latest conceptual drawings; however, the deviations will not appreciably affect the internal loads distribution.

TABLE A-1. APPLIED RACK JOINT FORCES AND MOMENTS

Lift-Off (Condition 1)

Joint No.	F_X (lb)	F_Y (lb)	F_Z (lb)	M_X* (in.-lb)	M_Y** (in.-lb)	M_Z*** (in.-lb)
5	6 895	2 775	- 68	0	- 487	- 6 470
6	10 723	4 589	673	0	-2 450	-13 600
7	1 920	2 177	23	0	0	0
8	25 258	6 501	- 60	0	0	-12 000
9	2 013	3 017	-1 027	0	0	0
10	2 018	2 053	35	0	0	0
11	18 857	3 833	-1 034	0	0	- 7 400
12	2 433	1 189	931	0	0	0
13	4 089	4 089	- 176	0	0	25 600
14	11 734	3 254	-1 167	0	0	0
15	3 645	3 175	24	0	0	17 100
16	11 560	1 274	-1 013	0	0	0
17	15 145	3 855	929	0	0	45 900
18	2 308	2 346	- 87	0	0	0
19	11 873	3 454	1 027	0	0	1 900
20	2 459	2 352	- 86	0	0	0
25	27 800	19 500	0	0	0	1 100 000

TABLE A-1. - Concluded

Lift-Off (Condition 2)

Joint No.	F_X (lb)	F_Y (lb)	F_Z (lb)	M_X* (in.-lb)	M_Y** (in.-lb)	M_Z*** (in.-lb)
5	9 704	297	5 876	0	33 300	
6	10 160	310	5 661	0	30 600	
7	1 533	1 052	3 341	0	0	0
8	14 209	659	2 340	0	0	-1 970
9	1 742	1 049	1 240	0	0	0
10	1 680	- 914	1 182	0	0	0
11	15 048	-1 620	1 858	0	0	4 520
12	1 472	-1 054	2 870	0	0	0
13	3 116	- 143	2 961	0	-25 600	0
14	10 701	741	1 562	0	0	0
15	12 030	-1 202	3 310	0	-17 100	0
16	1 444	- 14	2 868	0	0	0
17	14 630	-1 071	5 691	0	-45 900	0
18	1 760	126	2 684	0	0	0
19	1 827	205	3 314	0	- 1 900	0
20	10 992	1 104	3 507	0	0	0
25	27 800	0	19 500	0	-1 100 000	0

* M_X - Applied bending moment about an axis parallel to the global X-axis (Figure A-11).

** M_Y - Applied bending moment about an axis parallel to the global Y-axis (Figure A-11).

*** M_Z - Applied bending moment about an axis parallel to the global Z-axis (Figure A-11).

C. Power

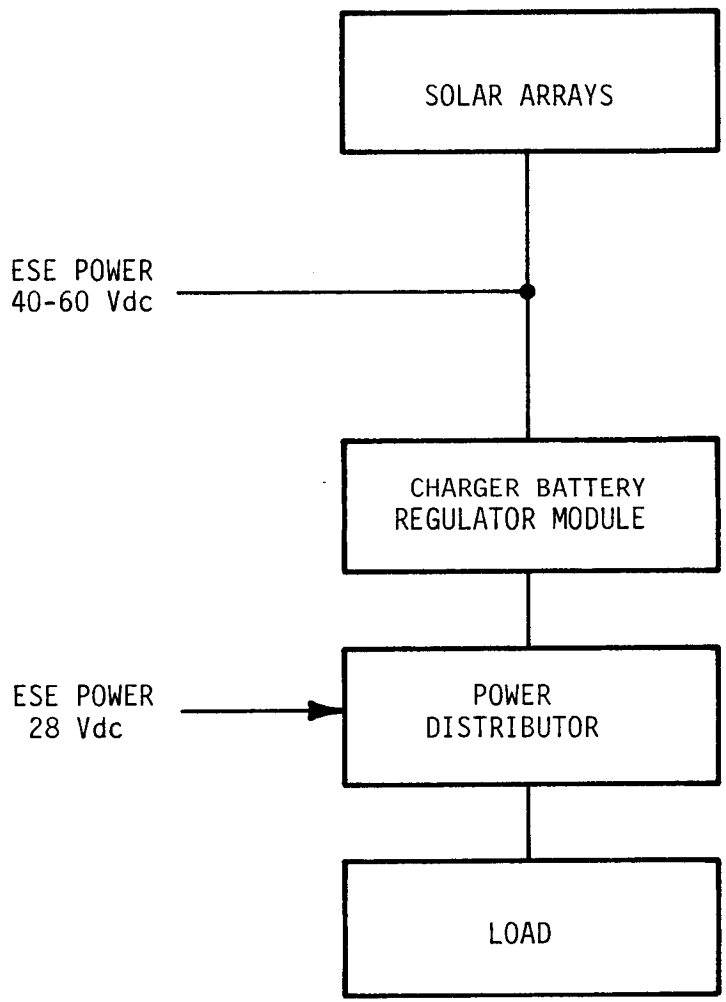
1. Introduction. Compared to previous Earth orbital satellites the manned ATM-B mission sets forth unique conditions which make the selection and design of an optimum power system difficult considering the schedule, the integration concept, economy, and the need to extend the operational life of the LM with minimum change. The selection of an adequate power system must be limited to well established technology to be consistent with the manned rating requirements and to be compatible with the basic LM systems and the overall mission requirements. Consequently, an ATM-A solar array with rechargeable batteries was used by this study.

2. Power Requirements. The values shown in Table 5 represent nominal operating values for equipment previously flown on Saturn vehicles (Ref. 10). New or revised equipment values are based on best estimates and on data derived from the experiment descriptions. Past experience has shown that in some cases these requirements represent "worst case" conditions and that actual requirements may be somewhat lower.

3. System Description. The solar cell array configuration consists of four wings which are deployed by use of a scissor truss. Figure A-12 is a block diagram of the electrical power system.

4. Size Determination. The solar array-battery rechargeable power system has been determined for the following mission profile:

- Orbit: 230 nautical miles circular
- Inclination: 28.5 degrees
- Orbital period: 93 minutes
- Minimum time in sunlight: 57 minutes
- Maximum time in darkness: 36 minutes
- Orientation of the solar panels: $90° \pm 15°$ solar vector.



NOTES:

1. 32 SOURCES
   2 SOURCES PER PANEL
   4 PANELS PER WING
   4 WINGS PER VEHICLE

2. 2 DIODES PER CHARGER BATTERY REGULATOR MODULE

3. 20 CHARGER BATTERY REGULATOR MODULES (CBRM)

4. EACH OF THE 20 CBRMs HAVE TWO OUTPUT LINES, ONE CONNECTED TO EACH OF THE TWO BUSSES

FIGURE A-12. ATM-B POWER SYSTEM BLOCK DIAGRAM

To determine the battery capacity and the size needed, a 25-percent depth of discharge as on ATM-A has been assumed.

Assuming that load regulators would operate with an 80 percent efficiency, the power required during darkness P_N is

$$P_N = P_L/\text{Regulation efficiency}$$

$$P_N = \frac{3385}{0.80} = 4231 \text{ watts}$$

where P_L is the average load power required during the dark portion of the orbit. The battery discharge current is

$$I_B = \frac{P_N}{V_B} = \frac{4231}{28} = 151 \text{ amps} \quad .$$

Battery discharge in ampere-hours (A·H) is

$$\left(\frac{36}{60}\right) (151) = 91 \text{ amp-hrs} \quad .$$

Battery system capacity for 25 percent discharge is

$$C = \frac{91}{0.25} = 364 \text{ amp-hrs} \quad .$$

Using a NiCd unit and 20 A·H rated cell, the number of parallel batteries required is

$$\frac{364}{20} = 18.2 \text{ or } 19 \text{ units.}$$

To afford a reserve, 20 units will be used.

5. <u>Solar-Cell Array Power Calculations</u>. Theoretical power density values of a solar-cell array can be determined from the following equation:

$$P_s = \eta S R C K_1 K_2 K_3 K_4 D_e M \quad [1 - (T_c - 28) D_t]$$

where

P_s - specific power (watts/ft^2)

S - solar intensity (127.0 watts/ft^2)

R - ratio of active cell area to overall gross array area (0.94)

C - correction for cover glass losses (0.98)

K_1 - correction for mismatch losses (0.98)

K_2 - correction for process degradation (0.985)

K_3 - correction for calibration and test errors (0.96)

K_4 - correction for solar constant uncertainty deviation (0.945)

D_e - Correction for environmental degradation (0.97)

M - Correction for misorientation (±15°, 0.966)

T_c - Cell operating temperature in °C (65°C for 250 n. mi.)

D_t - Cell temperature degradation coefficient (0.45 percent/°C)

η - Cell efficiency air mass zero (AMO) 11 percent.

Factors K_1, K_2, K_3, and K_4 are random variables. The RMS equivalent of the composite variance of these factors is RMS (K_1 K_2 K_3 K_4) = 0.928. Using the above parameters the specific power of the array is

$$P_s = (0.11)(127)(0.94)(0.98)(0.928)(0.97)(0.966)[1 - (37)(0.0045)]$$

$$= 9.33 \text{ W/ft}^2 \quad .$$

6. Solar-cell Array Configuration. Each solar cell module is complete in itself and contains 684 silicon solar cells (2 by 2 cm) mounted to the substrate with six cells operating in parallel and 114 cells operating in series. The total weight of each module including solar cells, cover slides, electrical wiring, adhesives and substrate is 4.831 pounds. The power rating under one solar constant at 70°C is 23.0 watts which gives a module power-to-weight ratio of 5.35 watts per pound.

On a panel basis with 20 modules per panel and including frame work but not deployment mechanism hardware, the power-to-weight ratio drops to 3.51 watts per pound. Figure A-13 is a diagram of the solar array and a typical module. Figure A-14 shows the solar cell array power and temperature versus orbital time characteristics. This figure indicates the strong dependence of the solar array available power output on its operating temperature.

7. Charger-Battery-Regulator Module. The power from the solar sources is fed on redundant lines directly to each Charger-Battery-Regulator (CBR) Module. The circuitry of the CBR is such that power is fed to both the charger and the regulator.

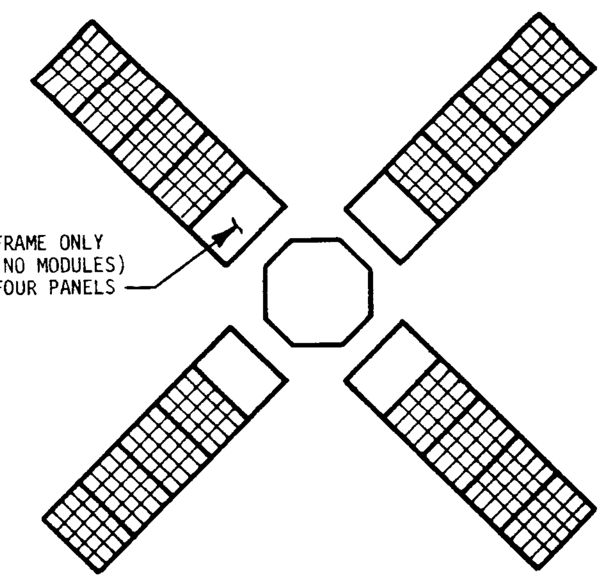
The solar array is the prime power source and provides the required power to the load and charges the batteries during the time the spacecraft is in sunlight. Power is supplied by the batteries when the solar panel voltage drops below the battery open circuit voltage (28 volts nominal) which occurs during the dark time period, during peak load requirements, and before the deployment of the solar panels.

Third-electrode batteries are used in the CBR modules. The third electrode allows internal battery sensing to prevent overcharging, thereby prolonging battery life. The battery capacity is 20-ampere hours with a depth of discharge of approximately 25 percent.

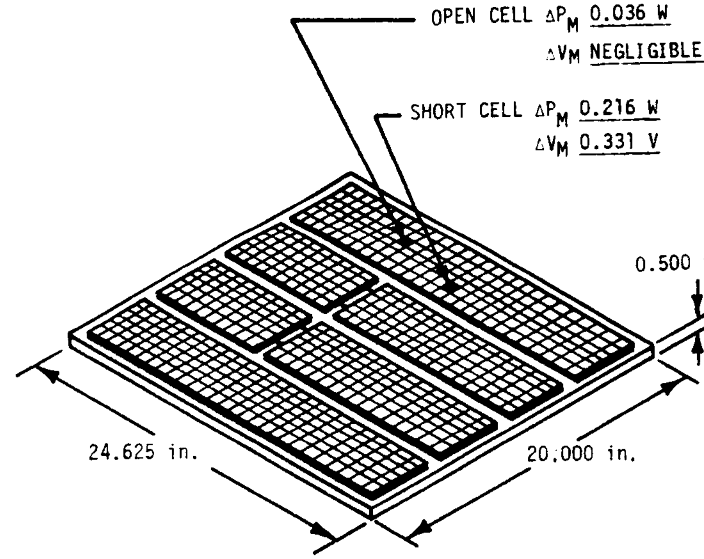
Figure A-15 shows the general configuration of the CBR module. Figure A-16 is a schematic of the CBR module. The load regulator is designed to provide overload protection as shown in Figure A-17. This protection limits the current output to 10 amperes thereby preventing a castastrophic failure due to a short circuit. The design meets the specifications that the output voltage be maintained between 27 and 30 volts from no load to 270 watts with a ripple of less than 100 millivolts at a frequency of 5 to 10 kHz. A summary of the electrical power conversion system is given in Table A-2.

CONFIGURATION:
20 MODULES/PANEL
4 PANELS/WING
4 WINGS/ARRAY

WEIGHT:
170 POUNDS/PANEL
(WITHOUT DEPLOYMENT HARDWARE)



a. SOLAR ARRAY



CONFIGURATION:
SOLAR CELLS
6 PARALLEL, 114 SERIES
2 CM x 2 CM
N/P, 10 OHM-CM, 10% EFFICIENCY
0.012 IN. QUARTZ COVERSLIDES

b. TYRICAL MODULE

FIGURE A-13. SOLAR CELL ARRAY

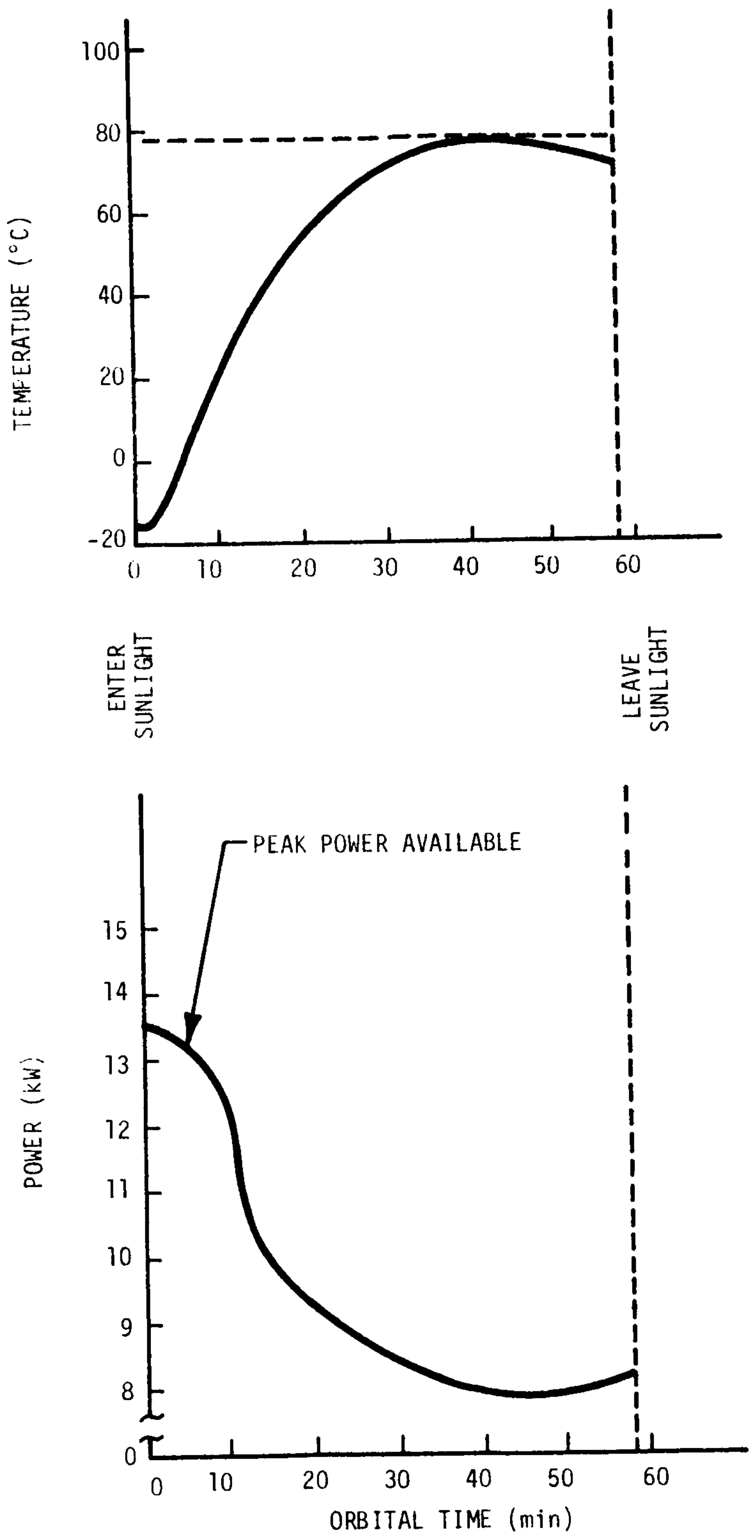
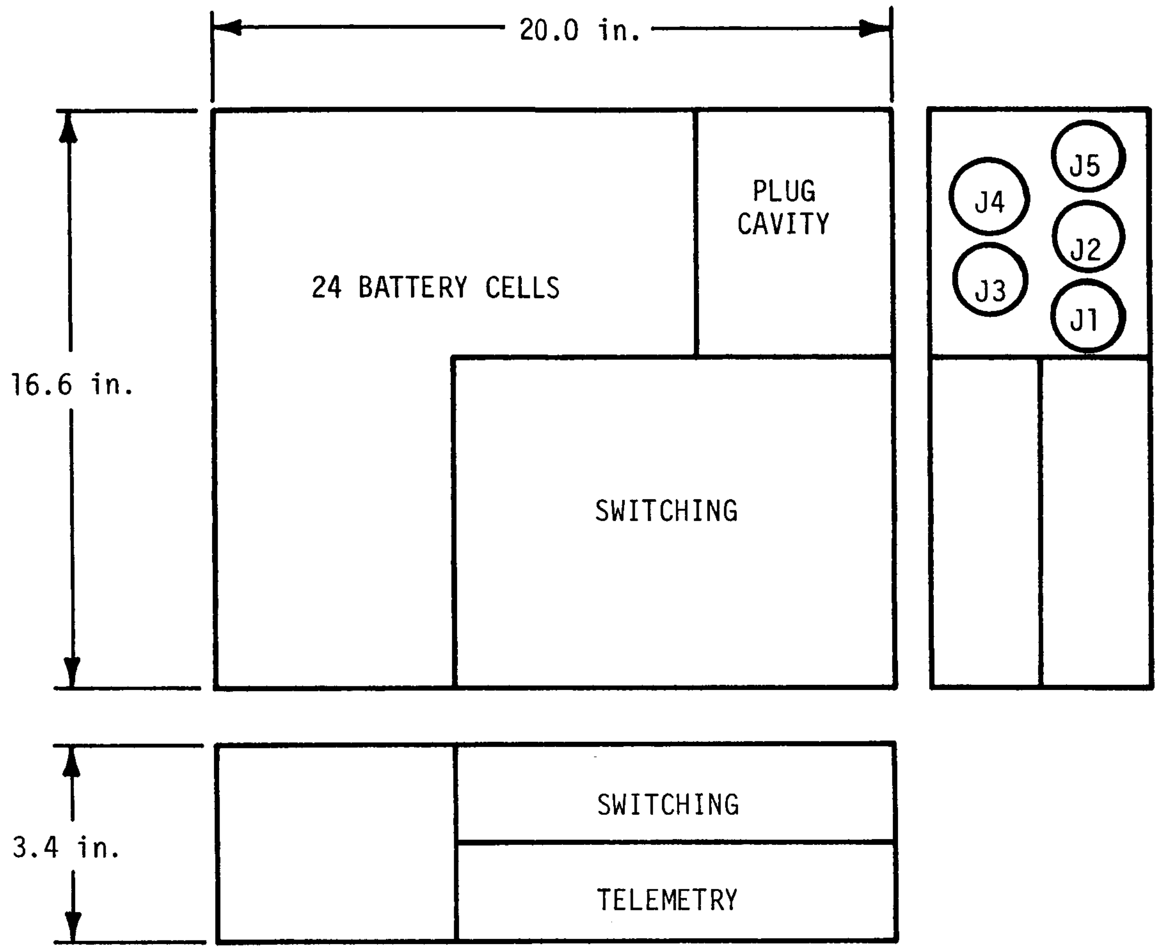


FIGURE A-14. SOLAR ARRAY POWER VERSUS TEMPERATURE NOMOGRAPH



TOTAL WEIGHT 85 POUNDS
J1 - SOLAR ARRAY
J2 - OUTPUT
J3 - TELEMETRY
J4 - ASTRONAUT FUNCTIONS
J5 - BATTERY CONDITIONING

FIGURE A-15. CHARGER/BATTERY/REGULATOR MODULE

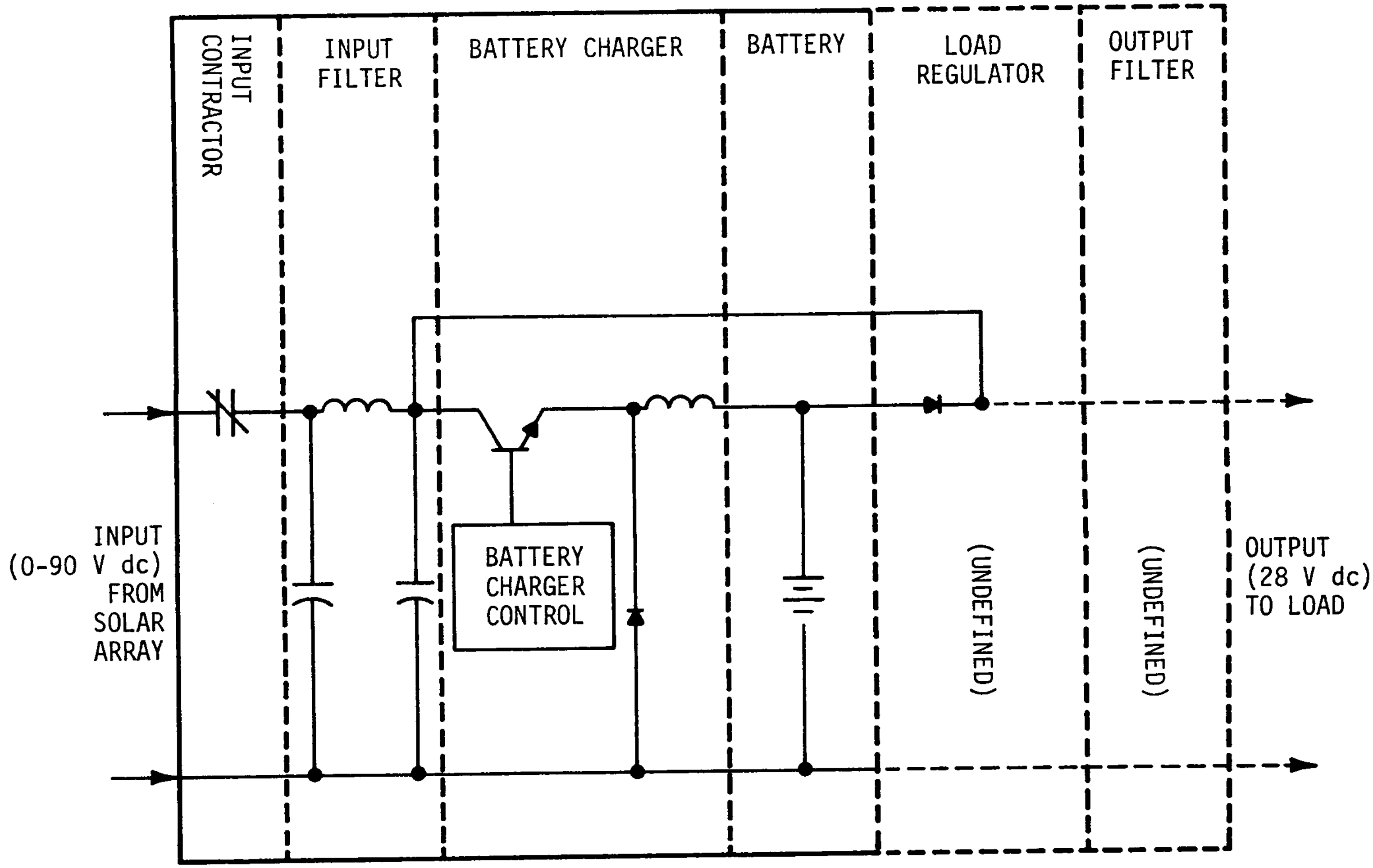


FIGURE A-16. CHARGER/BATTERY/REGULATOR MODULE SCHEMATIC

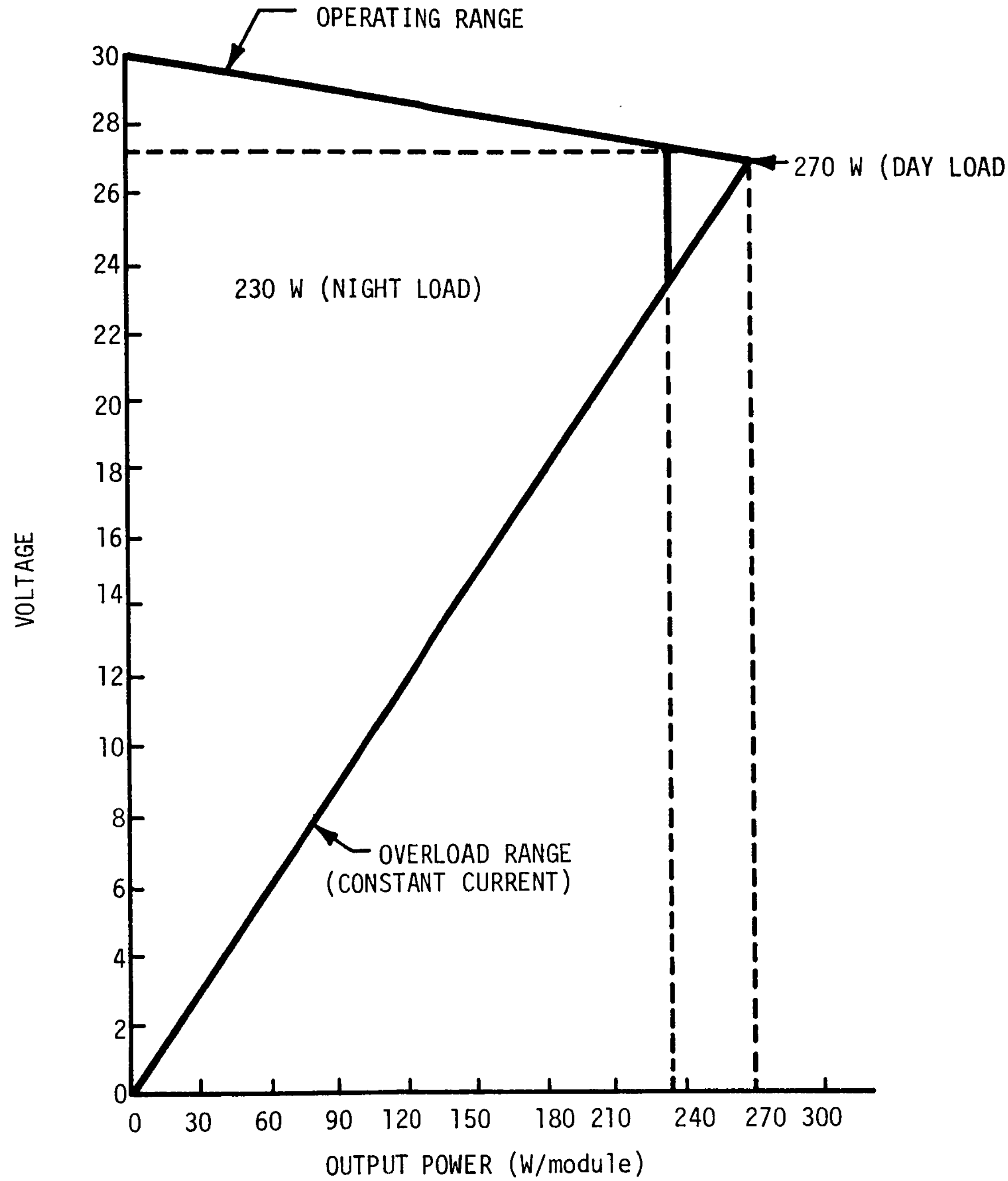
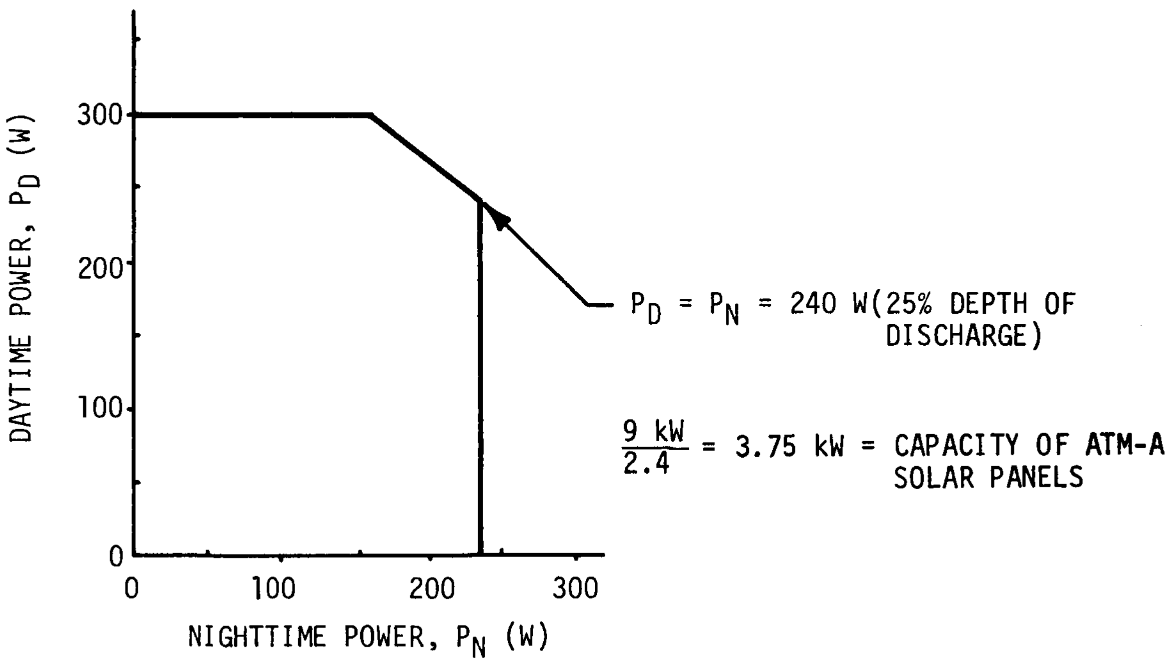


FIGURE A-17. LOAD REGULATOR CHARACTERISTICS

TABLE A-2. ELECTRICAL POWER CONVERSION SYSTEM SUMMARY FOR ATM-B

- NUMBER OF CBR MODULES REQUIRED 20
- INPUT:
  - SOLAR ARRAY VOLTAGE . . . . 40-75 Vdc
  - SOLAR ARRAY POWER (P_{SA}) (16 PANELS) . . . 9 kW AVERAGE* (57 MIN/93 MIN. ORBIT)
- BATTERY: MAXIMUM DEPTH-OF-DISCHARGE . . . . 25% SAME AS ATM-A
- OUTPUT:
  - VOLTAGE
    - STEADY STATE . . . . 29-31 Vdc
    - RIPPLE . . . . 0.1 V_{PK-PK} MAX. AT 5-10 kH_Z
- BATTERY CAPACITY:
  - PEAK . . . . ≈5.2 kW



- SYSTEM PERFORMANCE FACTOR = 2.4 (SOLAR ARRAY TO LOAD FOR ENTIRE ORBIT).

* BASED UPON UPRATED ATM-A SOLAR ARRAY CAPACITY - APPROX. 12 kW FOR 20 PANELS

8. Power Distribution System. The regulator input voltage, either solar supplied or battery supplied, is regulated to 28 ±1 Vdc and fed to the parallel load busses in the main power distributor.

The main power distributor contains two load busses which distribute power to the ATM-B loads in parallel. The loss of any one of these busses should have no effect upon system power. Figure A-18 is a block diagram of the ATM-B power distribution system.

In the main power distributor the main power drains upon the system are separated. The LM ascent power, the CMG inverter power and the pointing control system power are removed from the main power stream and distributed from this point. The remaining power is routed to the auxiliary power distributor for distribution to secondary loads. All loads except LM power are relay controlled with redundant relays and all lines contain short circuit protection. Figures A-19 and A-20 illustrate the main and auxiliary distributor systems, respectively.

The CMG inverters and the 5 Vdc measuring supplies are considered as secondary power sources in the system. There are three CMG inverters, each of which feeds a separate CMG. Two of these inverters also are available to provide power for the rate gyros. Loss of one inverter will not compromise the mission. There are two 5 Vdc measuring supplies which provide redundant measuring system voltage to the system. Loss of one supply will not affect the 5 Vdc system.

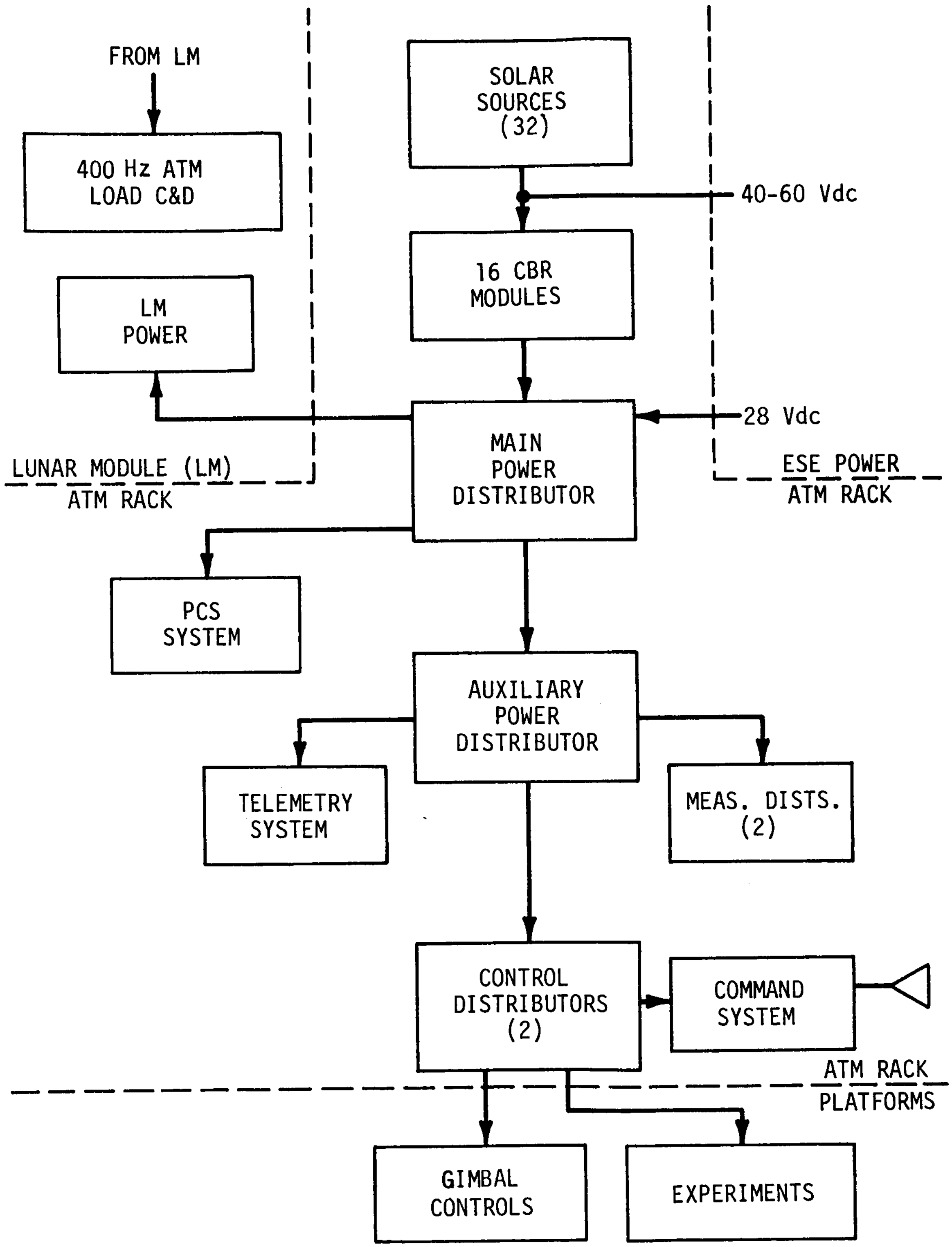


FIGURE A-18. ATM-B POWER DISTRIBUTION SYSTEM

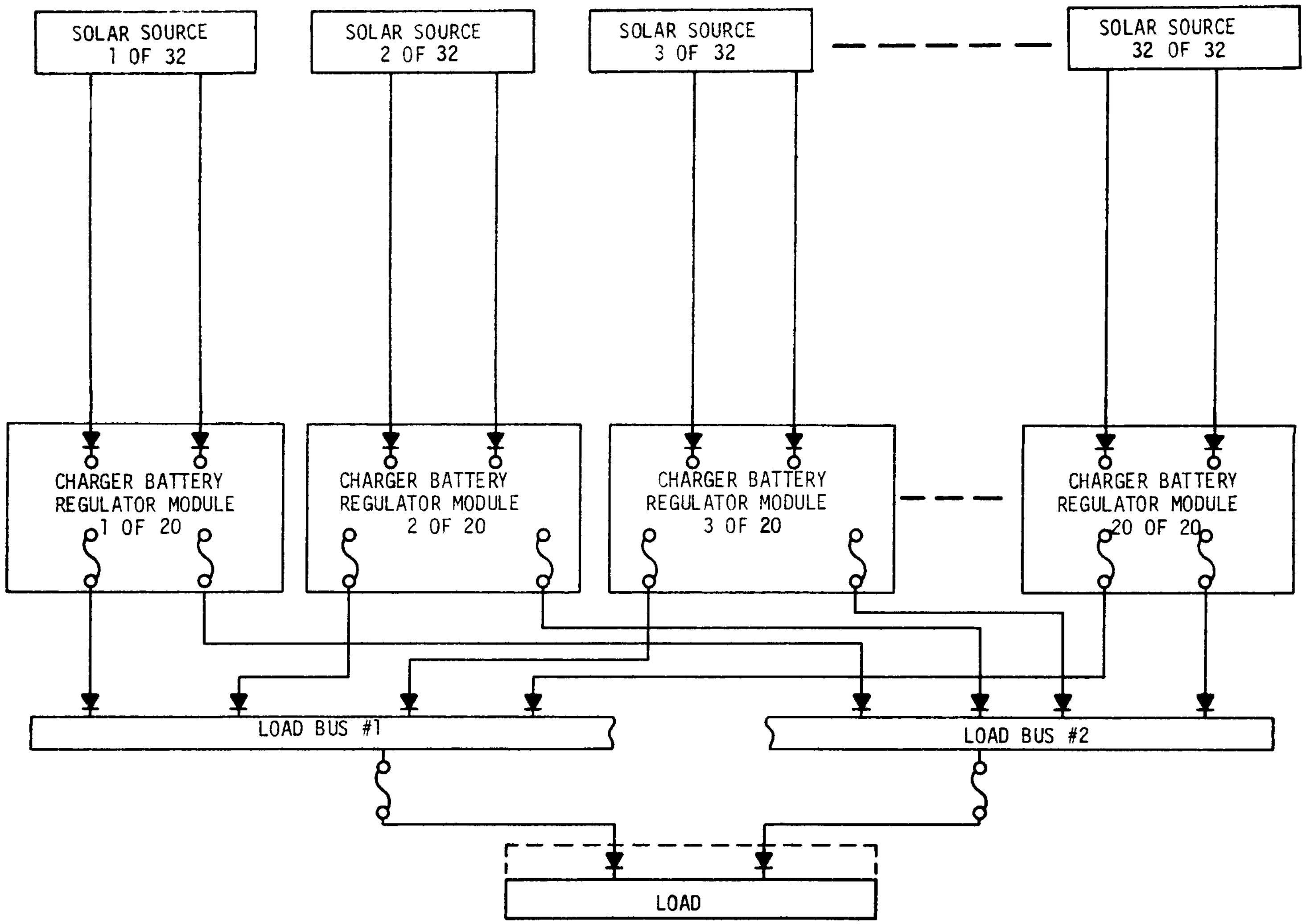


FIGURE A-19. MAIN POWER DISTRIBUTOR SYSTEM

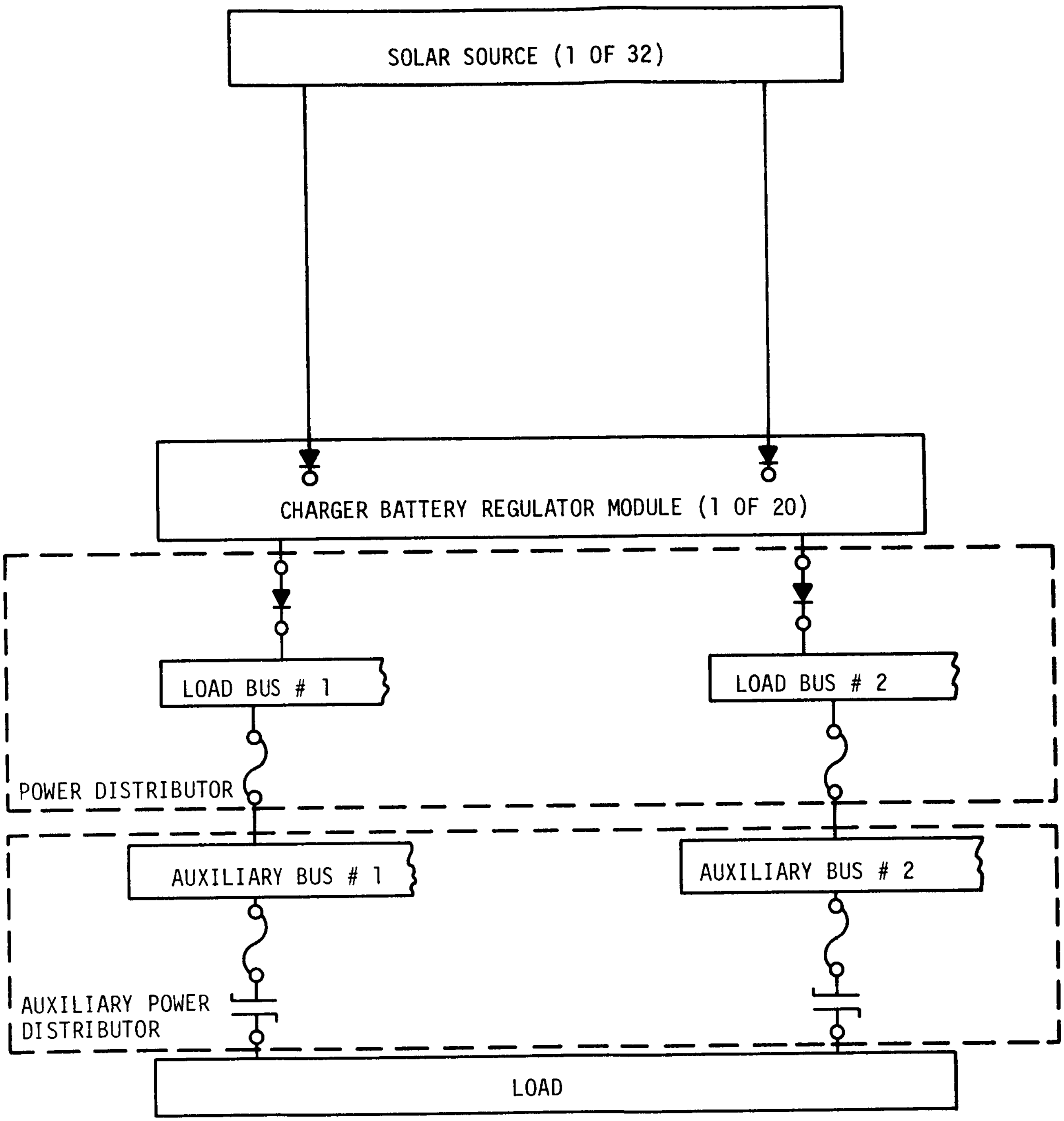


FIGURE A-20. AUXILIARY POWER DISTRIBUTOR SYSTEM

D. Instrumentation and Communications

1. Introduction. The Instrumentation and Communications (I&C) subsystem for ATM-B will be located within the rack and will be essentially independent of the LM ascent stage. It consists of measuring, telemetry, command, antenna, and television subsystems which will be designed to provide the following functions. There will be approximately 400 ATM-B measurements telemetered. These measurements are related to vehicle checkout, environmental control, electrical, power, and pointing control systems, and experiment scientific and housekeeping data. A command link will be provided for checkout and activation of systems. A closed circuit television subsystem for experiment monitoring will be provided.

Voice communications between the LM and CSM and the LM and ground will be provided by the basic LM communication subsystem when operating separately. When the LM is docked to the MDA, the primary voice communications will be provided by hard line audio circuits to the CSM. Similarly, after docking, primary communications between the LM and the MSFN will rely on the hard line audio link to the CSM and the CSM radio frequency links to the MSFN.

This I&C subsystem will:

- Satisfy the requirements of ATM-B for which it is specifically designed
- Use highly reliable, flexible, flight proven Saturn hardware
- Require no substantial interface between the rack and the LM ascent stage
- Use Saturn data formats and radio frequencies to maintain compatibility with existing ground station capabilities
- Provide continuous orbital coverage of all scientific data and selected housekeeping data via onboard recording, auxiliary storage and playback assemblies (ASAP)

- Provide a command up-link capability for checkout and activation of systems prior to initial operation and subsequent to orbital storage

- Provide a closed-circuit television system for experiment monitoring and targeting

- Provide the most feasible methods for factory, prelaunch, and orbital checkout of ATM-B systems and provide maximum compatibility with existing prelaunch checkout equipment

- Minimize training requirements for MSFC, KSC, and contractor personnel.

2. Measurement-Telemetry Requirements. Principal Investigators' estimates of measurement-telemetry requirements were obtained for each of eight ATM-B experiments. Sampling rates and number of words (each word is 10 bits) per sample have been itemized in Table A-3.

The requirements for the ATM-B subsystems are itemized in Table A-4. This data has been derived from MSFC instrumentation programs for the ATM mission, with appropriate changes reflecting the differences in subsystems for ATM-B.

The total bit rate for real time telemetry of 35.22 kbits/sec is well within the capacity of the PCM DDAS system, 72 kbits/sec.

The data storage rate for the ASAP unit, 6.414 kbits/sec, exceeds the capacity of a single ASAP unit. Each ASAP records data at 4 kbits/sec, with 3.88 kbits/sec available for data and 120 bits/sec utilized for frame identification. Therefore, two ASAP units are provided, as shown in Figure 22.

3. Description of the I&C Subsystem. The I&C subsystem consists of measuring, telemetry, command, antenna, and television subsystems.

a. Measuring Subsystem. The measuring subsystem consists of transducers and signal conditioners. There are approximately 400 ATM-B measurements to be telemetered. These measurements are related to vehicle checkout, environmental control, power, electronic and pointing control systems, and experimental scientific and engineering data.

TABLE A-3. SCIENCE DATA TELEMETRY REQUIREMENTS

Experiment and Investigator	Number of Words per Measurement Versus Sampling Rate		
	Real Time Telemetry (samples/sec)	ASAP (samples/sec)	
	40	1	4
Ultraviolet Photography Survey (Tifft-Univ. Arizona)	Housekeeping Data Only (160 bits/sample - 1 sample/15 min)		
Far Ultraviolet Spectrographs (Carruthers-NRL)	Housekeeping Data (10 samples/hr)		
Modulated Collimator X-Ray (Gursky-AS&E)	5.0		50
Low Energy γ-Ray Sky Survey (Frost-Goddard SFC)	2.5	100	
Digitized Spark Chamber (Fichtel-Goddard SFC)	2.0	80	
Medium Energy γ-Ray and X-Ray Spectroscopy (Peterson-Univ. California)	2.5	100	
X-Ray Sky Survey Panels (Friedman-NRL)	3.6		36
Far Ultraviolet Spectrograph (Morton-Princeton University)	Housekeeping Data Only		
Spark Chamber (Frye-Case Institute of Technology)	Housekeeping Data (10 kbits/day)		
TOTAL	15.6	280	86

TABLE A-4. ATM-B SYSTEMS MEASUREMENT TELEMETRY REQUIREMENTS

		Number of Words per Measurement Versus Sampling Rate					
		Real Time Telemetry (samples/sec)				ASAP (samples/sec)	
		4	12	40	120	1	4
SCIENTIFIC DATA FROM TABLE A-4				15.6		280.0	86.0
FLIGHT CONTROL COMPUTER	Temperature	3.0					
	Register Verify		1				
ICA	Voltage Dump (P, R, Y)	3.0					
FLIGHT MODE		1.7					
CMG	Temperature	8.0					
	Voltage-Instantaneous Momentum-(X, Y, Z & TOTAL)		4				
	Vibration (Gyro)		6				
	Gimbal Angle Position		6				
	Gyro Wheel Speed (RPS)	3.0					
	Tachometer-Gimbal (2X, 2Y, 2Z)		6				
	Command Voltage	9.0		3.0			
	Gyro - Emergency Shut Down	0.3					
	Lock	0.3					
	Disconnect Command	0.3					
RATE GYROS	Temperature		2				
	Gain (Roll, Yaw, Pitch)	0.3					
	Commands (R, Y, P)				3.0		
	Resolved (Y, P)		2				
	Torque (R, Y, P)		3				
	Integrator Voltage (R, Y, P)	3.0					
SUN SENSOR (ACQUISITION)	Acquisition	0.1					
	Presence	0.1					
	Yaw		1				
	Pitch		1				
	Orbital Plane Command		1				
STAR TRACKER	Drive Voltage (Y, P)	2.0					
	Error Voltage (Y, P)			2.0			
	Gimbal (Y, P)				2.0		
	Housekeeping	0.4					
BOOM ANGLES (SUB-COMMUTATED)		3.4				3.4	
UV PLATFORM GIMBAL ANGLES			4			4.0	
ELAPSED TIME MISSION CLOCK		2.5					2.5
COMMAND RECEIVER	Signal Strength (hi, low)		2				
	Decoder Address Verify Pulse				0.2		
SELECTOR SWITCHES (4 each)	Output				4.0		
	Execution Signals				2.0		
POWER SUBSYSTEM	Battery Modules (temp., voltage)	48.0					
	Power Modules (current, voltage, charge-discharge)	72.0					
	Load Bus Voltages	2.0					
	Solar Panel (temp., short-circuit current)	21.0					
REMOTE ANALOG SUBMULTIPLEXER	Calibration	8.0	4				
TEMPERATURE MONITORS		18.0					
	TOTAL	209.4	43	20.6	11.2	287.4	88.5
	Kilobits Per Second	8.376	5.16	8.24	13.44	2.874	3.54
	TOTAL KILOBITS PER SECOND	35.216				6.414	

The transducers are located at selected measuring points and are electrically connected to the measuring racks. A modular signal conditioning arrangement provides compatibility between the various transducer outputs and the input characteristics of the telemetry subsystem. The modular concept of signal conditioning provides a high degree of configuration and maintenance flexibility.

b. Telemetry. The telemetry subsystem receives measurements from vehicle checkout, environmental control subsystem, power, electronic, and pointing control systems, and experimental scientific and engineering data systems. The measurement inputs to the telemetry subsystem are analog and digital signals generated by transducers or signal conditioners. The telemetry subsystem contains equipment for analog and digital multiplexing, encoding, formating, storage, and playback and transmission.

The Model 103 Remote Analog Sub-Multiplexer (RASM) receives analog signals directly from the signal conditioners. With time division multiplexing, these signals are delivered to the Model 270 Analog Multiplexer where they are formated into a serial wavetrain.

Most digital inputs come through the Model 410 Remote Digital Sub-Multiplexer (RDSM). Discrete or digital data are temporarily stored in the RDSM and sent out in a repeating sequence to the Model 301 Assembly.

The Model 301 Pulse Code Modulation/Digital Data Acquisition System (PCM/DDAS) Telemeter is an encoder-multiplexer assembly that accepts, encodes, and time integrates pulse amplitude modulation (PAM) analog signals, discrete signals, and digital signals. The master electronic clock is included in the Model 301 Assembly to initiate numerous synchronizing signals for the other components of the subsystem. There is a primary and a redundant PCM/DDAS assembly. Their outputs -- parallel digital and serial digital to transmitters, and 600 kHz FM carrier -- are selected by the amplifier and switch assembly.

A parallel output from the PCM/DDAS assembly is routed to the ASAP units where experiment data are extracted and recorded for up to 90 minutes. The stored data are then played back, by astronaut or ground command, in 5 minutes over a ground station. During playback, the ASAPs provide the PCM wavetrain through the amplifier and switch assembly to 10 watt VHF transmitters. Three transmitters are provided for redundancy. Both the PCM/DDAS assembly and the ASAP units provide a 600 kHz FM carrier as the DDAS output for use during testing, checkout, and prelaunch.

c. Command. The digital command subsystem is composed of a MCR-503D command receiver and command decoder to provide the required command inputs to the switch selectors and the ATM flight control computer. The command receiver (carrier frequency 450 MHz) is modulated by a phase shift keyed composite baseband waveform containing binary intelligence. The receiver separates the baseband data from the carrier and feeds it to the decoder where it is demodulated. The decoder recovers the transmitted 35 bit command word, performs an error check, and presents 18 information bits to be used as required by the switch selectors and flight control computer.

d. Antenna Subsystem. The antenna subsystem consists of two scimitar or notch telemetry antennas and a slot command antenna (antennas mounted at ends of solar panel wings), two coaxial switches, and a command directional coupler.

This system uses redundance of the telemetry transmitters by modulating both transmitters with the same information. Although the two telemetry antennas are operating simultaneously, the antenna patterns are independent due to the difference in operating frequencies.

Studies are being performed to investigate the effects upon the antenna pattern of the ATM cluster configuration.

e. Television Subsystem. The television subsystem consists of a camera, sync generator, and video monitor. The subsystem is closed circuit and no video information will be transmitted to the MSFN.

The TV camera will be mounted on the ultraviolet experiments platform and will be bore-sighted with the ultraviolet experiments. The monitor in the LM control and display panel will present a 6-inch diameter display with a resolution of 600 lines horizontally and 300 lines vertically. An electronic cross hair will serve as an aid in pointing the ultraviolet platform at selected source targets.

E. RCS Propellant Requirements for Attitude Control

1. Attitude Disturbances. There are several types of attitude disturbances during Earth orbit (Ref. 11). The resulting torques about the cluster X, Y, and Z axes produce disturbance momentums as functions of the moments of inertia about the three axes. These disturbance torques and resulting momentums must be countered by the attitude thrusters on the LM in order to fulfill the above attitude holding requirements. The propellant required by the LM engines depends upon the magnitudes of the various attitude disturbances listed below.

Continuously Acting	Randomly Acting
Gravity Gradient	Astronaut Motion
Aerodynamic	Motion of Platform Experiment Arms
Solar Pressure	Micrometeorite Impact
Magnetic Field Effects	Shift of Cluster Center of Gravity Due to Propellant Used from Attitude Propellant Tanks
Precession of Orbital Plane Due to Energy Dissipation	

The disturbances due to solar pressure, Earth's magnetic field, and micrometeorite impact have negligible effects. These disturbance torques range between 10^{-2} to 10^{-8} times the gravity gradient and aerodynamic torques. Crew motion disturbances are assumed to be random in nature. The acceleration induced by a crew member is cancelled when the motion is terminated. Thus only steady state changes in orientation and position are experienced. It has been observed that the maximum shift of the principal axes due to astronaut motion is very small. Thus control system cross coupling is negligible.

Since the platform experiment arms and the LM propellant tanks are very close to the cluster center of gravity, movements in these two bodies has negligible effect on shifting the center of gravity of the cluster to generate a disturbance in attitude.

Precession of the orbital plane due to energy dissipation from the cluster causes the gravity gradient and aerodynamic torques to shift values about the Y and Z axes. Resulting propellant consumption by the attitude thrusters is accounted for by assuming the worst case angle between the orbital plane and the Sun line, γ, during the 56-day mission.

a. Gravity Gradient and Aerodynamic Torques. These torque disturbances are cyclic and are of considerable value during each orbit (Figures A-21 and A-22). The calculated quantity of LM/RCS propellants required is based on the amount for the LM thruster system to produce a quantity of momentum equal to that produced by the continuously acting gravity gradient and aerodynamic torques.

b. Gravity Gradient Torque. A gravity gradient is established along, for example, the longitudinal or X axis of the cluster if, e.g., the OWS section is closer to the center of the Earth than is the CSM section. The OWS section would then have a higher acceleration due to gravity than would the CSM section. As a result there would be a gravity gradient torque about the cluster Y axis tending to draw the OWS section closer to the center of the Earth.

The gravitational torque on the cluster about its center of gravity is given by

$$\overline{T}_P = -\frac{3\mu}{R_P^3}\left[\frac{R_Y R_Z}{R_P^2}(I_{ZZ} - I_{YY})i + \frac{R_X R_Z}{R_P^2}(I_{XX} - I_{ZZ})j + \frac{R_X R_Y}{R_P^2}(I_{YY} - I_{XX})k\right],$$

where R_P is the distance from the center of gravity of the cluster to the center of the Earth (Ref. 12).

It is necessary to choose a reference attitude, and for convenience let the Z axis lie along the radius vector R_P from the cluster center of gravity to the center of the Earth. Since there can be no torque on this axis, only two attitude angles are required to define the orientation. For a rotation order in which the cluster is first rolled in a positive sense through an angle Ψ about the X axis, and pitched through angle Φ about the Y axis,

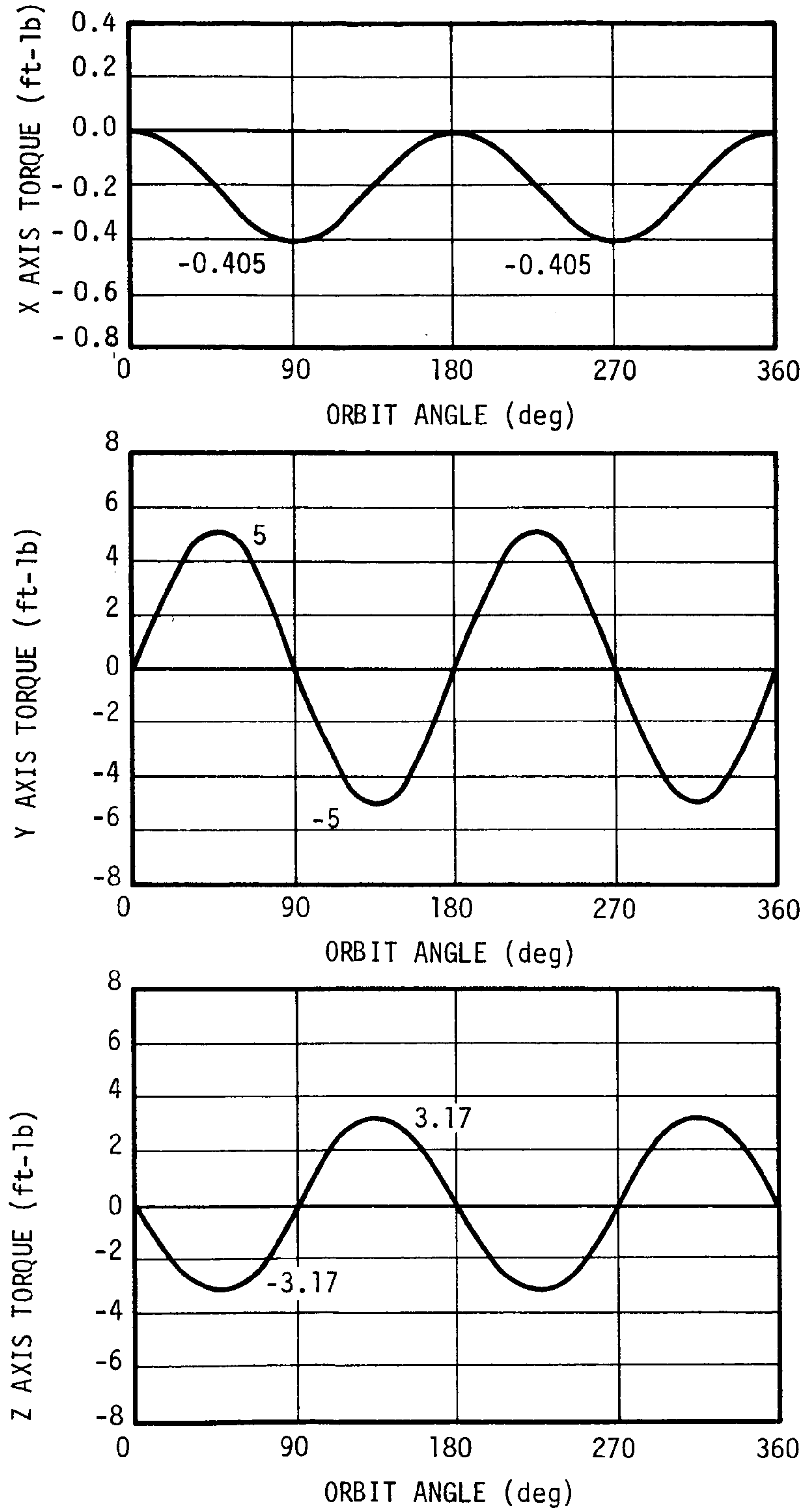


FIGURE A-21. GRAVITY GRADIENT DISTURBANCE TORQUES

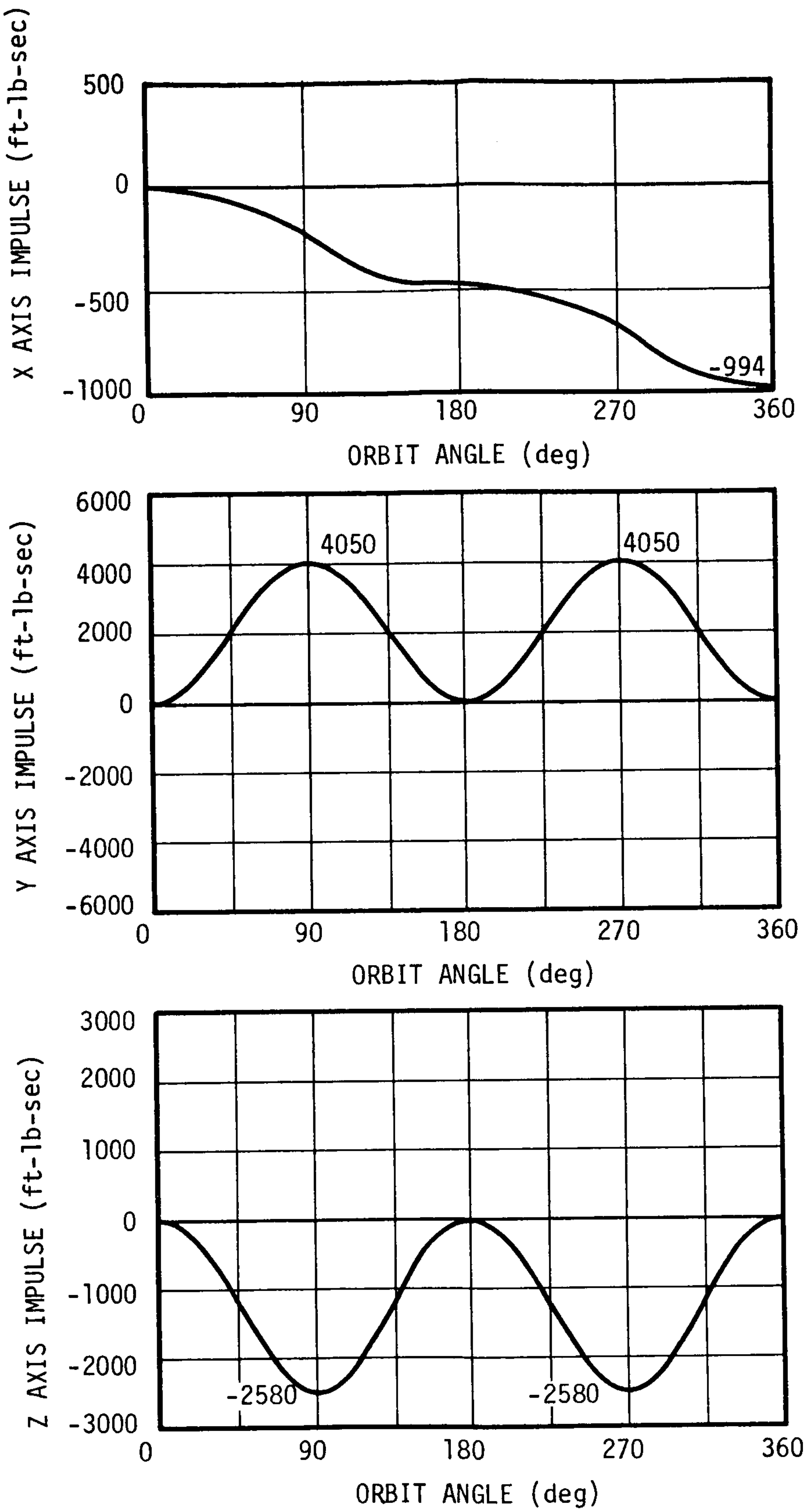


FIGURE A-22. GRAVITY GRADIENT DISTURBANCE IMPULSE

$$R_x = - R_p \sin\phi \cos\Psi$$

$$R_y = R_p \sin\Psi$$

$$R_z = R_p \cos\phi \cos\Psi \ .$$

Substituting these expressions into the torque equation gives

$$M_x = - \frac{3\mu}{2R_p^3} \cos\phi \sin 2\Psi (I_{zz} - I_{yy})$$

$$M_y = - \frac{3\mu}{2R_p^3} \sin 2\phi \cos^2 \Psi (I_{zz} - I_{xx})$$

$$M_z = - \frac{3\mu}{2R_p^3} \sin\phi \cos 2\Psi (I_{xx} - I_{yy}) \ .$$

The gravity gradient moments are cyclic, and assuming the variation to be sinusoidal, the average moment about the Y axis is

$$(M_y)_{Avg.} = \frac{3\mu}{2\pi R_p^3} |I_{xx} - I_{zz}| \ .$$

The maximum values of the cyclic components about the X and Z axes are given by

$$(M_x)_{Max} = \frac{3\mu}{2R_p^3} |I_{zz} - I_{yy}|$$

$$(M_z)_{Max} = \frac{3\mu}{2R_p^3} |I_{yy} - I_{xx}| \ .$$

The angular momentums contributed by the gravity gradient torques are $(\text{Impulse})_{cycle}$ = Peak Cyclic Torque x$(\tau_0/2\pi)$ lb-ft sec per orbit, and $(\text{Impulse})_{cycle}$ = Average Torque $\times \tau_0$ lb-ft-sec per orbit, where τ_0 is the orbital period.

c. Aerodynamic Torque. Aerodynamic torque acting on the cluster is given by

$$\overline{T}_a = \frac{C_d}{2} \rho_a \overline{V}^2 A_{ref} \overline{C}_{ref} ,$$

where

C_d - coefficient of drag

ρ_a - atmospheric density

$\overline{V}$ - velocity vector of the cluster

A_{ref} - projected areas of the cluster

$\overline{C}_{ref}$ - reference length from center of pressure to center of gravity.

The center of pressure is computed from the information contained in Figure A-23: Projected areas of the cluster components and moment arm lengths from the component centers of pressure to the cluster center of gravity.

The center of pressure does not coincide with the center of mass. This produces a pitch-over torque. The torque tends to stabilize the cluster in the direction of the incident wind stream, only if the center of pressure is located downstream of the center of mass. Now the ATM-B will have its Z axis along the Sun line of sight. Thus the aerodynamic torques will be cyclic, changing from stabilizing to destabilizing, one cycle of values, throughout each orbit.

The aerodynamic impulse developed due to the torque is given by

$$\text{Impulse} = \int_0^t \overline{T}_a dt = \int_0^t \frac{C_d}{2} \overline{V}^2 A_{ref} \overline{C}_{ref} \rho_a \, dt .$$

2. <u>LM/RCS Propellant Requirements.</u>

a. Calculations of Moments of Inertia. Calculations of the LM/RCS propellant requirements were based on the cluster configuration as shown in Figure A-24. Component weights are given as follows:

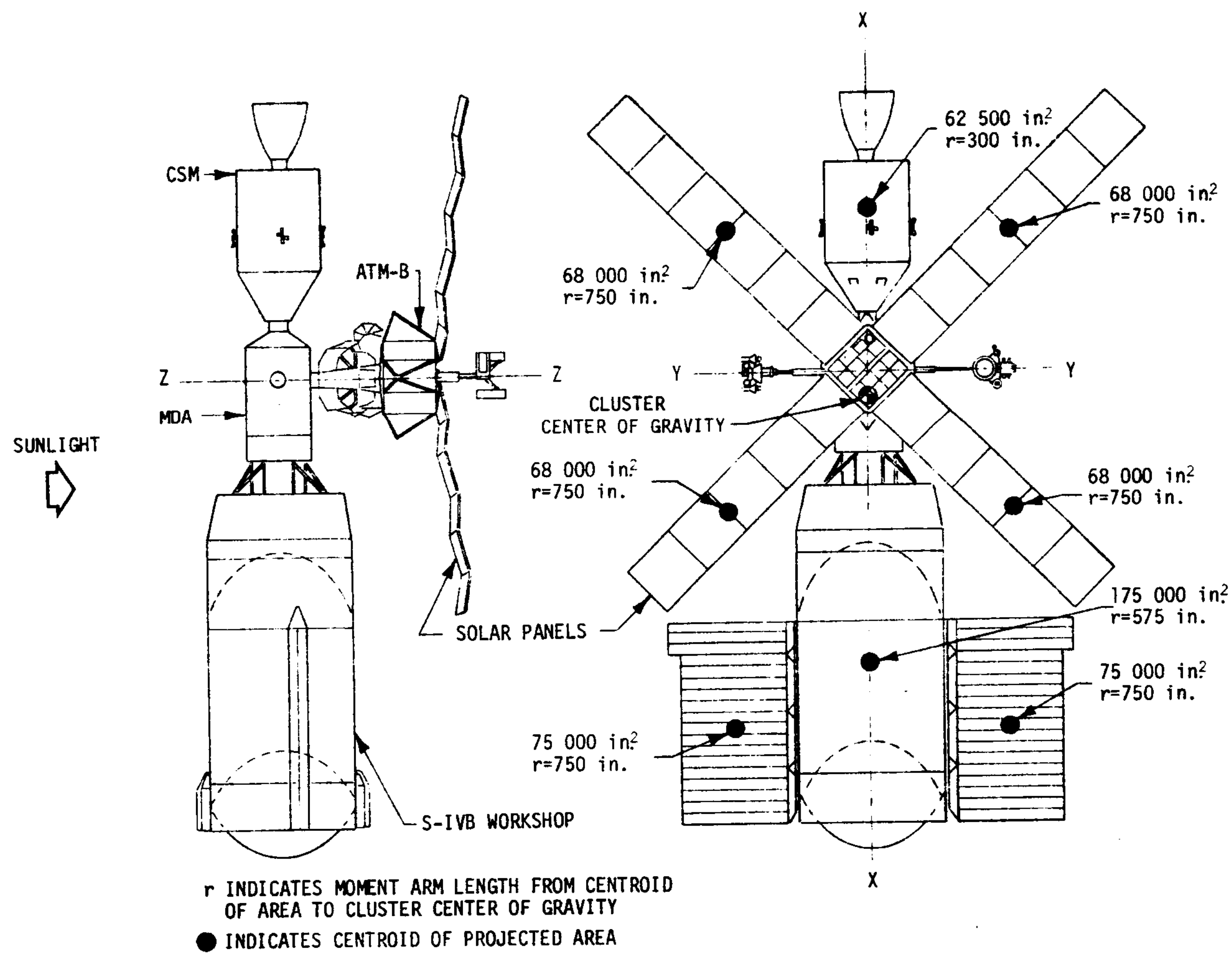


FIGURE A-23. PROJECTED SURFACE AREAS AND MOMENT ARMS OF COMPONENTS OF CLUSTER CONFIGURATION I FOR AERODYNAMIC TORQUE CALCULATIONS

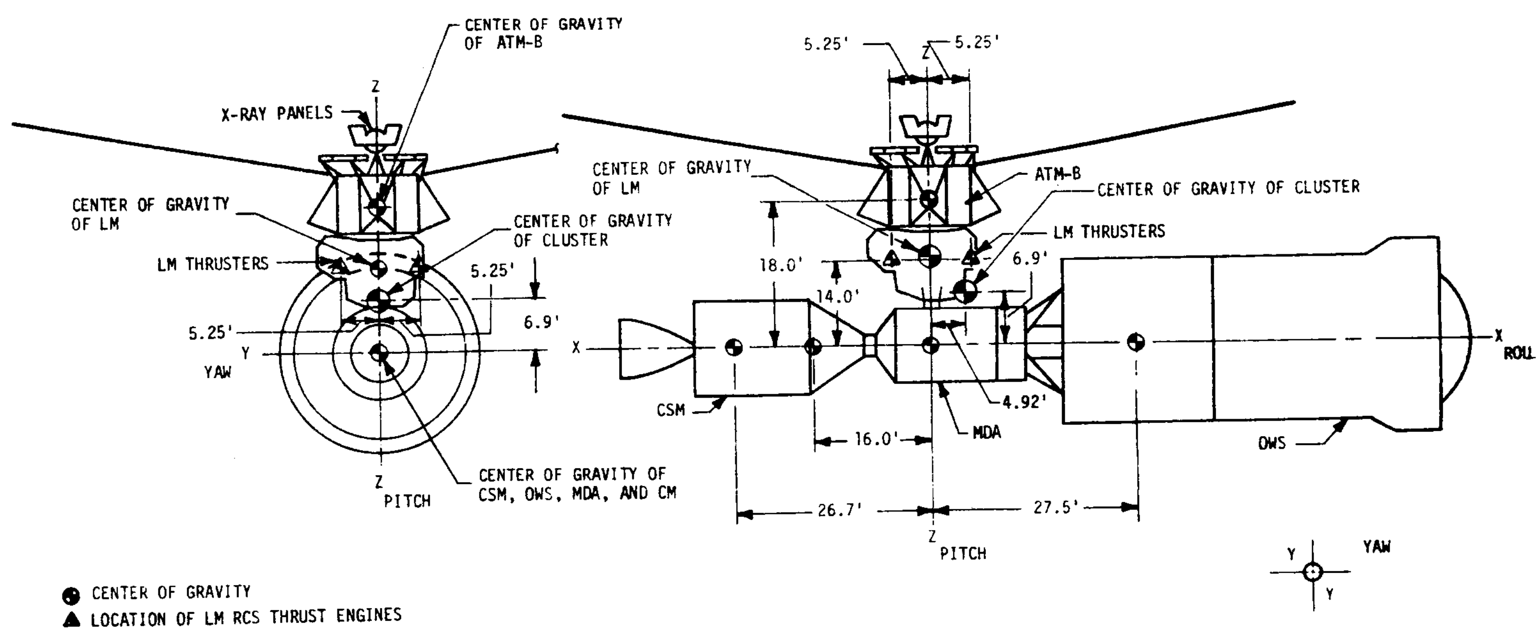


FIGURE A-24. ATM-B CLUSTER CONFIGURATION I

Component	Weight (lb)
LM/ATM-B, Configuration II	32 478
Service Module	11 300
Command Module	12 100
Multiple Docking Adapter and Airlock Module	3 000
Orbital Workshop	35 500

The mass moments of inertia about the cluster X, Y, and Z axes are:

$$I_{xx} = \sum m \overline{R}^2 = \frac{32\,478}{32}(11.1)^2 + \frac{(11\,300 + 12\,100 + 3\,000 + 35\,500)}{32}(6.9)^2$$

$$= 2.16 \times 10^5 \text{ lb ft sec}^2 \ .$$

$$I_{yy} = \frac{32\,478}{32}(11.9^2 + 4.9^2) + \frac{11\,300}{32}(31.62^2 + 6.9^2)$$

$$+ \frac{12\,100}{32}(6.9^2 + 20.92^2) + \frac{3\,000}{32}(4.92^2 + 6.9^2)$$

$$+ \frac{35\,500}{32}(22.58^2 + 6.9^2)$$

$$= 1.326 \times 10^6 \text{ lb ft sec}^2 \ .$$

$$I_{zz} = \frac{32\,478}{32}(4.92)^2 + \frac{11\,300}{32}(31.62)^2 + \frac{12\,100}{32}(20.92)^2$$

$$+ \frac{3\,000}{32}(4.92)^2 + \frac{35\,500}{32}(22.58)^2$$

$$= 1.12 \times 10^6 \text{ lb ft sec}^2 \ .$$

b. Total Attitude Disturbance Impulses. The attitude disturbance impulses arising from the effects of gravity gradient and aerodynamic torques during each orbit, with the X axis in the orbital plane and the cluster Z axis along the line of sight from the cluster to the Sun, are found to be:

4910 ft-lb-sec impulse about the Z axis (peak value of cyclic impulse)

4210 ft-lb-sec impulse about the Y axis (peak value of cyclic impulse)

350 ft-lb-sec impulse about the X axis.

c. Propellant Requirements to Balance the Momentum Disturbances Produced by Gravity Gradient and Aerodynamic Torques.

(1) Z Axis. Assuming the specific impulse (I_{sp}) of each LM thruster is 225 seconds, propellant flow rate is given by

$$\text{Flow Rate} = \frac{2\ (4910)}{(5580)(10.5)(225)} = \frac{4.16}{5580}\ \text{lb/sec} \ .$$

For the 93-minute orbit there are 5 580 seconds. Assuming that two LM attitude thrusters fire together, the effective moment arm (distance between thrusters) is 10.5 feet.

Propellant required for a 56-day mission; for 15.3 orbits per day:

$$\frac{(4.16)(15.3)(56)(5580)}{5580} = 3564 \text{ pounds} \ .$$

(2) Y Axis.

$$\text{Flow Rate} = \frac{2\ (4210)}{(5580)(10.5)(225)} = \frac{3.564}{5580}\ \text{lb/sec} \ .$$

Propellant required for a 56-day mission:

$$\frac{(3.564)(15.3)(56)(5580)}{5580} = 3052 \text{ pounds} \ .$$

(3) X Axis.

$$\text{Flow Rate} = \frac{2\ (350)}{(5580)(10.5)(225)} = \frac{0.296}{5580}\ \text{lb/sec} \ .$$

Propellant required for a 56-day mission:

$$\frac{(0.296)(15.3)(56)(5640)}{5640} = 254 \text{ pounds} .$$

Thus the total propellant for the LM attitude thrusters required to balance the torque disturbances due to gravity gradient and aerodynamic effects is (3564 + 3052 + 254) pounds = 6870 pounds. This value increased by 15 percent safety factor is 7900 pounds for a 56-day mission.

d. Estimation of Required Propellants Quantity for ATM-B Based on Completely Simulated ATM-A. From a previous study involving a 28-day mission a 225 000 lb-sec impulse is required for control of all attitude disturbances about the X, Y, and Z axes (Ref. 9). The results are based on a complete digital computer simulation of the cluster and attitude control system dynamics. The attitude thrusters of the OWS provided the attitude control. The cluster configurations of the major components of ATM-A and ATM-B are the same; thus the principal moments of inertia are nearly the same, but the moment arms of the attitude thrusters of the ATM-A and ATM-B are different:

Moment Arms of Attitude Thrusters (ft):

AXIS	ATM-B	ATM-A
X	10.5	11.6
Y	10.5	46.8
Z	10.5	46.8

Assuming that the 225 000 lb-sec impulse is equally divided between the Y and Z axes for a 28-day mission, and that the propellant consumed based on this figure is inversely proportional to the moment arms of the attitude thrusters, the propellant requirements for this 56-day mission are calculated:

$$\text{Y axis:} \quad 2\,\frac{(225\ 000)(46.8)}{(2)(10.5)(225)} = 4\ 455 \text{ pounds}$$

for 225-second impulse of the ATM-B attitude thrusters.

$$\text{Z axis:} \quad 2\,\frac{(225\ 000)(46.8)}{(2)(10.5)(225)} = \underline{4\ 455} \text{ pounds.}$$

$$\text{Total} \qquad 8\ 911 \text{ pounds for 56-day mission.}$$

The disturbance torques about the X axis are relatively small, requiring less than 100 pounds of attitude propellant; the thruster moment arms about the X axis for the ATM-A and ATM-B are nearly the same length.

Estimation of propellant requirements based on completely simulated ATM-A is an upper limit value because the LM thrusters fire in pairs; this does not generate disturbance torques about the other axes, as is done when firing a single APS engine of the S-IVB stage.

3. <u>Location Rearrangement of the LM and CSM to Lengthen the Moment Arms of the LM Attitude Thrusters about the Y and Z Axes.</u> The effective moment arms of the LM thrusters about the Y and Z axes can be lengthened by exchanging places between the CSM and LM. The LM would be docked at Port No. 5 of the Docking Module, but the LM solar panels would have to be attached to the side of the ATM rack so that the solar panels could face the Sun while the cluster maintains the orientation: X axis in the orbital plane, with the pitch axis of the LM pointing along the Sun line of sight. Propellant requirements are decreased as the moment arms of the attitude thrusters are increased.

4. <u>Deterioration of Performance of Attitude Thrusters if Deflector Plates are Used to Keep Exhaust Plumes from the Solar Panels.</u> It was contemplated to use exhaust plume deflector plates to keep the heat of the exhaust plumes of the attitude thrusters of the LM from damaging the solar panels. Any impingement of the exhaust gas from a thruster upon an attachment to the cluster results in a loss of change in momentum of the cluster by the mass of gas impinging and its resulting velocity change.

Minimum impulse firing time duration is 7.5 milliseconds for the LM attitude thrusters.

$$\Delta t = \frac{I_m}{T} = \frac{0.75}{100} \text{ sec} = 7.5 \text{ milliseconds},$$

where

Δt - time duration of minimum impulse (sec)

I_m - minimum impulse (lb sec)

T - engine thrust (lb).

Thus there would be very little heat buildup on the solar panels resulting from minimum impulse firing from the attitude thruster every 4 seconds. This would be the average frequency of thruster firing, using 8 000 pounds of propellant over the 56-day period.

So from the two standpoints of possible deterioration of LM thruster performance and little heat buildup on the solar panels due to infrequent and short time interval firings of the attitude thrusters, it appears that deflector plates will not be required.

F. Thermal Control

A preliminary thermal analysis of the ATM-B experiments was performed for the cluster operational mode in Configuration I. Due to the different experiment thermal tolerances and methods of experiment packaging, no thermal comparison was made between ATM-A and ATM-B.

A thermal model for each major component of each experiment was programmed in an orbital heat flux computer program (Ref. 13). Only plane surfaces were used in each thermal model because the heat flux program would accept only rectangles, disks, and trapezoids. In several cases, cylinders were approximated by rectangular or octagonal boxes. The exposed area of the thermal model approached the area of the actual experiment. The effects of the ATM-A solar panels, the LM, the ATM-A rack structure, the S-IVB, and other boundary surfaces were included in each thermal model analysis. These effects accounted for the shading and reflection between the cluster surfaces. The surfaces of the thermal models and other cluster surfaces were assigned a solar absorptivity and emissivity representative of severe thermal conditions for the operational mode. These conditions would exist on any surface that might be darkened, such as surfaces darkened by the plume of an RCS engine.

The orbital data used in the heat flux program were based on the cluster configuration with the S-IVB trailing the ATM-B while the cluster was in sunlight. The cluster was oriented so that the S-IVB was in front of the ATM solar panels relative to the Sun. The orbit considered was circular, 230 nautical miles in altitude, with an inclination of 28.5 degrees. This resulted in an orbit period of 1.5512 hours of which 1.0811 hours was spent in the sunlight.

The heat flux on each surface was calculated in terms of solar, albedo, and planetshine radiation. The solar radiation is the incident radiation from the Sun. The albedo is the reflected radiation from the Earth's atmosphere. The planetshine is infrared radiation due to the surface temperature of the Earth. Both direct incident radiation in Btu/ft^2-hr and total absorbed radiation in Btu/hr were calculated. The total absorbed radiation was used in the CINDA program (Ref. 14) because it included the reflected radiation between the cluster surfaces. The direct incident did not include this effect.

To complete the input required for the CINDA program, configuration factors between the experiment thermal models and the boundary surfaces were calculated. The thermal input to the CINDA program is based on an electrical circuit analogy. Radiation heat transfer path was represented by resistors and thermal capacity was represented by capacitors.

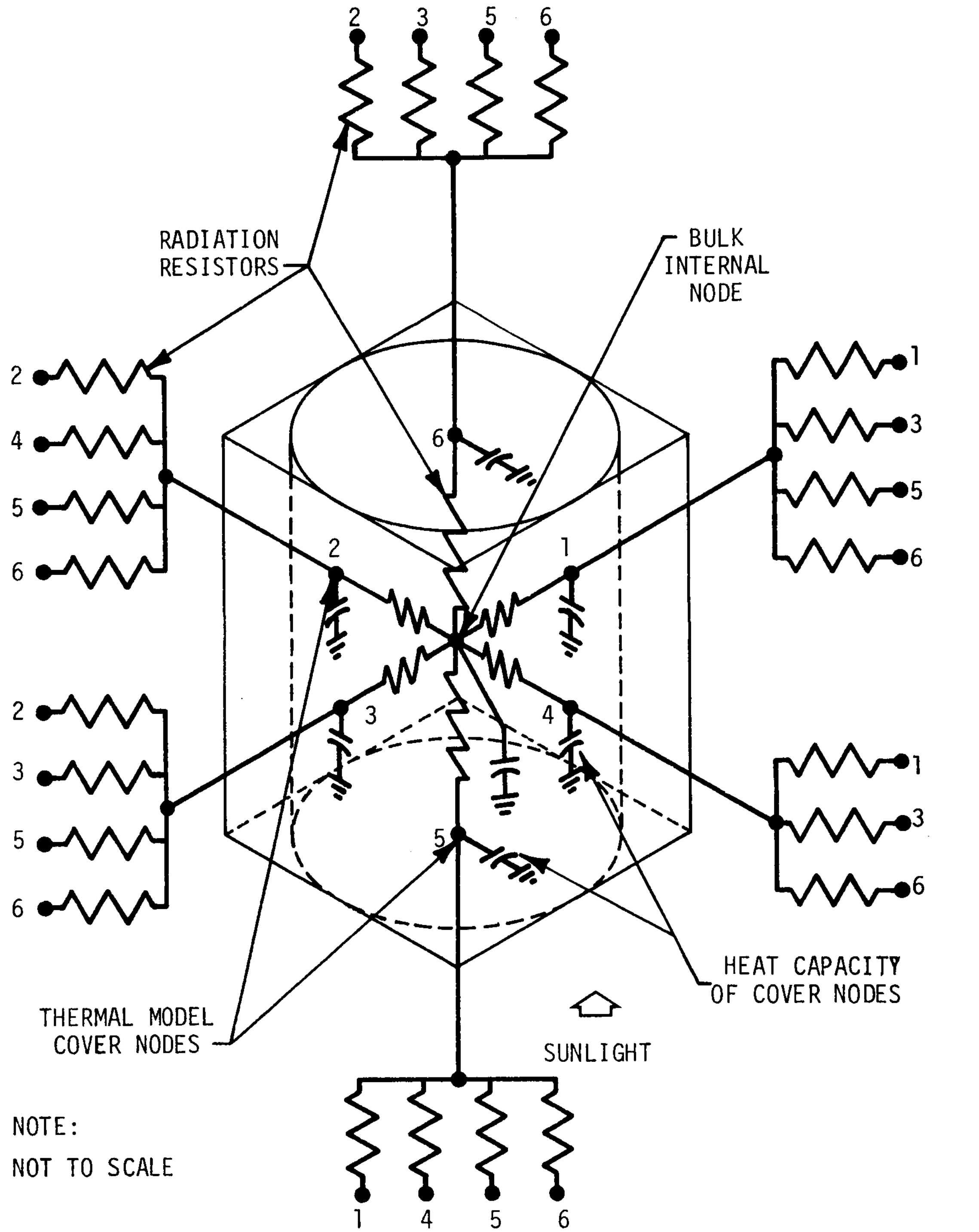
The heat capacity of each protective shell was input to the CINDA program. The internal mass of each experiment was input as a bulk mass in terms of a capacitor. The view factors from the protective shells to the internal mass were set at 1.0. The protective shell internal emissivity was set as that for a bare, oxidized metallic surface ($\epsilon = 0.22$ for aluminum) since data on internal coatings were incomplete.

The thermal model used for the Peterson gamma-ray detector is typical of other thermal models (Figure A-25). The orbital heat flux on this detector is shown in Figure A-26.

In the experiments which had power applied to the detector units rather than the electronic assemblies, the electrical power in watts became converted to a thermal load at the bulk mass capacitor. The radiation resistors were from each surface on the thermal models to the boundary surfaces. The orbital heat flux was cycled on to the surfaces of the thermal models for five orbits or approximately 8.0 hours. This allowed time for the temperatures to come to equilibrium so that the temperature of a surface at the end of one orbit period would be equal to the temperature of the same surface at the end of the next orbit period.

The cover temperatures and internal temperature of each experiment was then calculated. Typical temperature profiles are shown in Figures A-27 and A-28 for the Peterson gamma-ray detector.

The experiment cover temperatures varied from below 0°F for those covers not receiving direct sunlight to greater than 200°F for those covers in direct sunlight as shown in Table A-5. Most bulk internal temperatures did not vary out of the specified operating range. The



1. LM/ATM
2. SOLAR PANEL 3
3. SOLAR PANEL 2
4. S-IVB
5. DIGITIZED SPARK CHAMBER (MULTIPLE RESISTORS)
6. SPACE

FIGURE A-25. PETERSON GAMMA-RAY DETECTOR, THERMAL MODEL

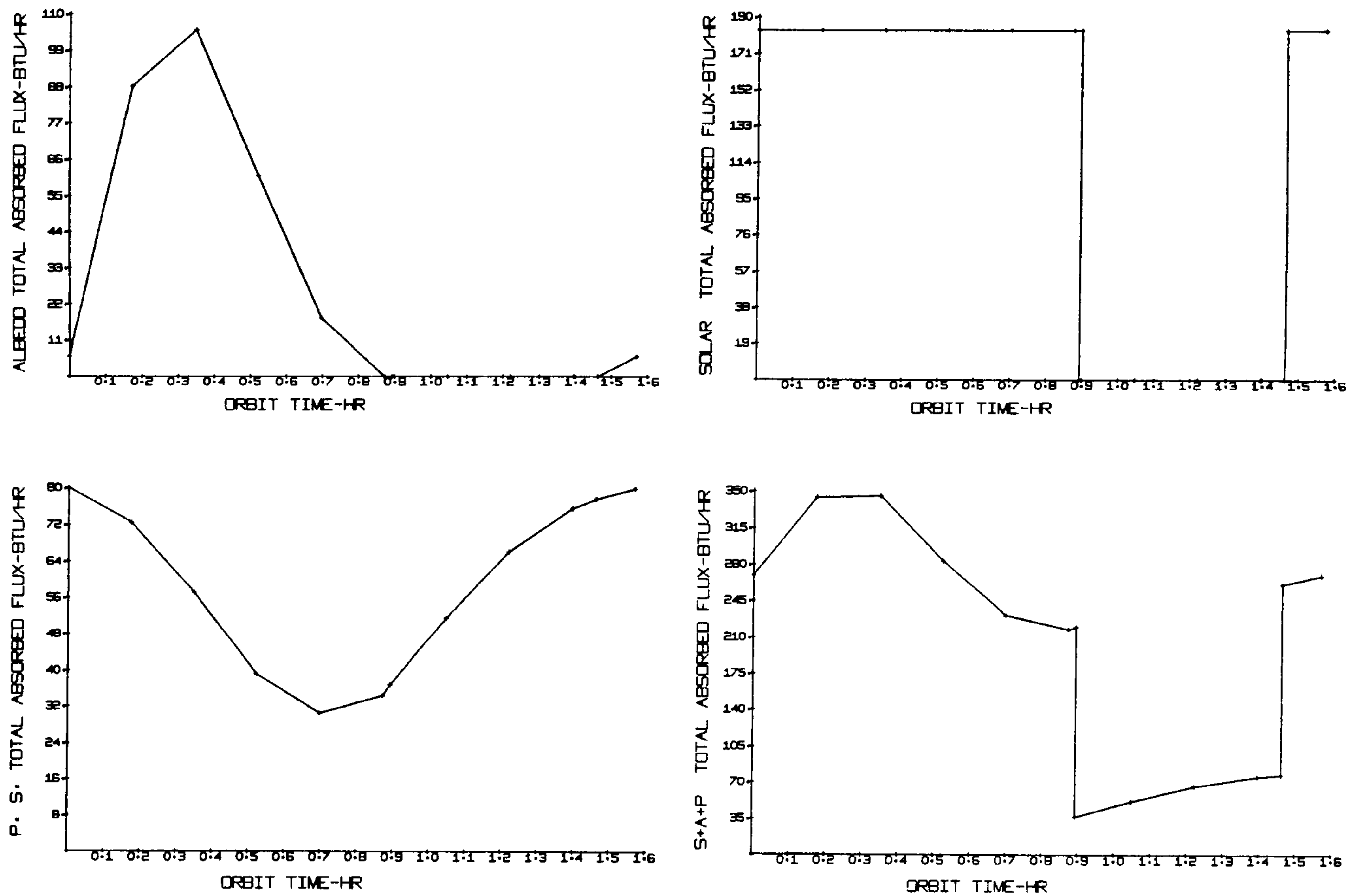


FIGURE A-26. SOLAR, ALBEDO, PLANETSHINE, AND TOTAL ABSORBED ORBITAL HEAT FLUX, PETERSON GAMMA-RAY DETECTOR, VERSUS TIME

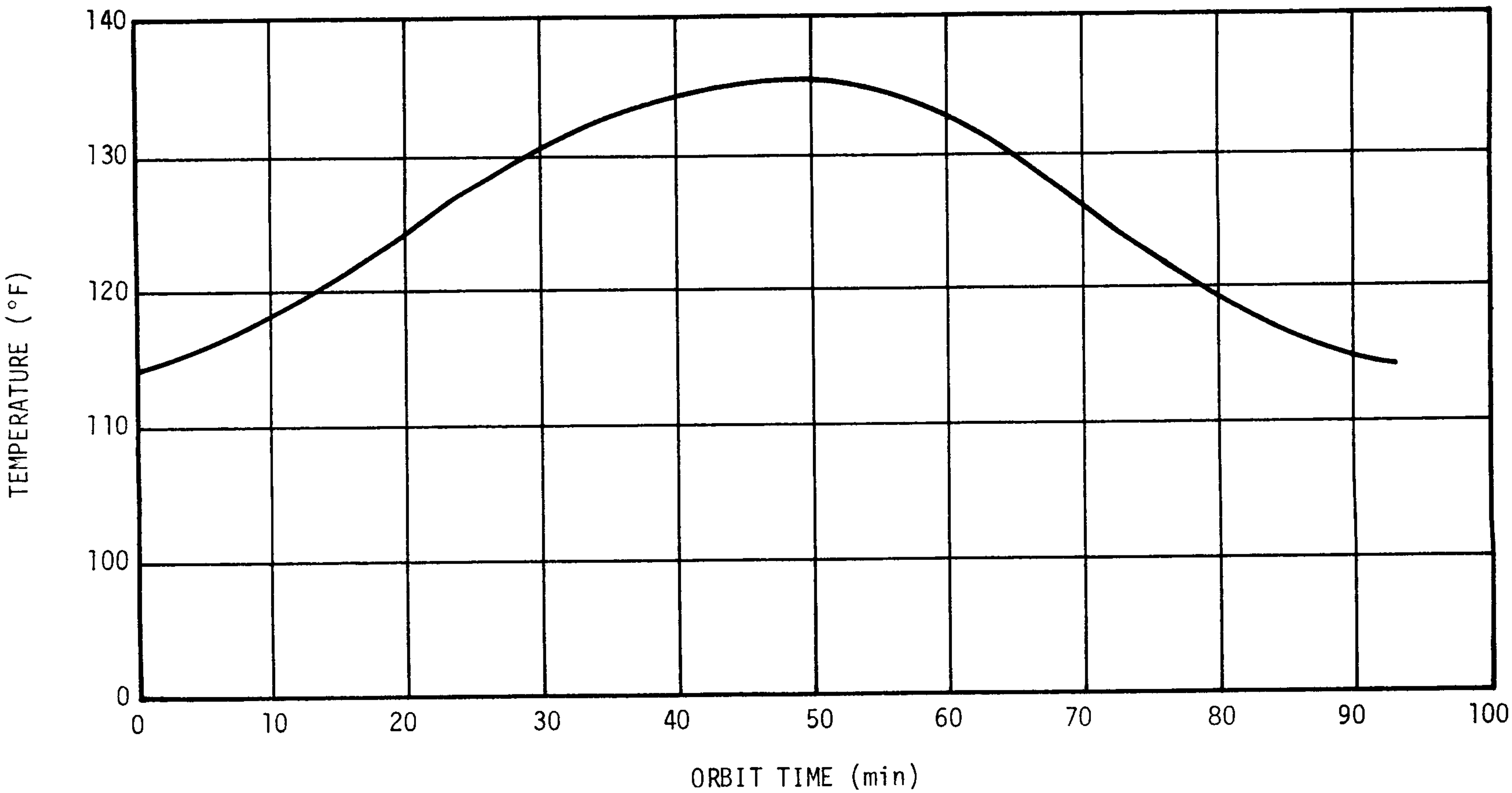


FIGURE A-27. INTERNAL TEMPERATURE, PETERSON GAMMA-RAY DETECTOR, VERSUS ORBITAL TIME

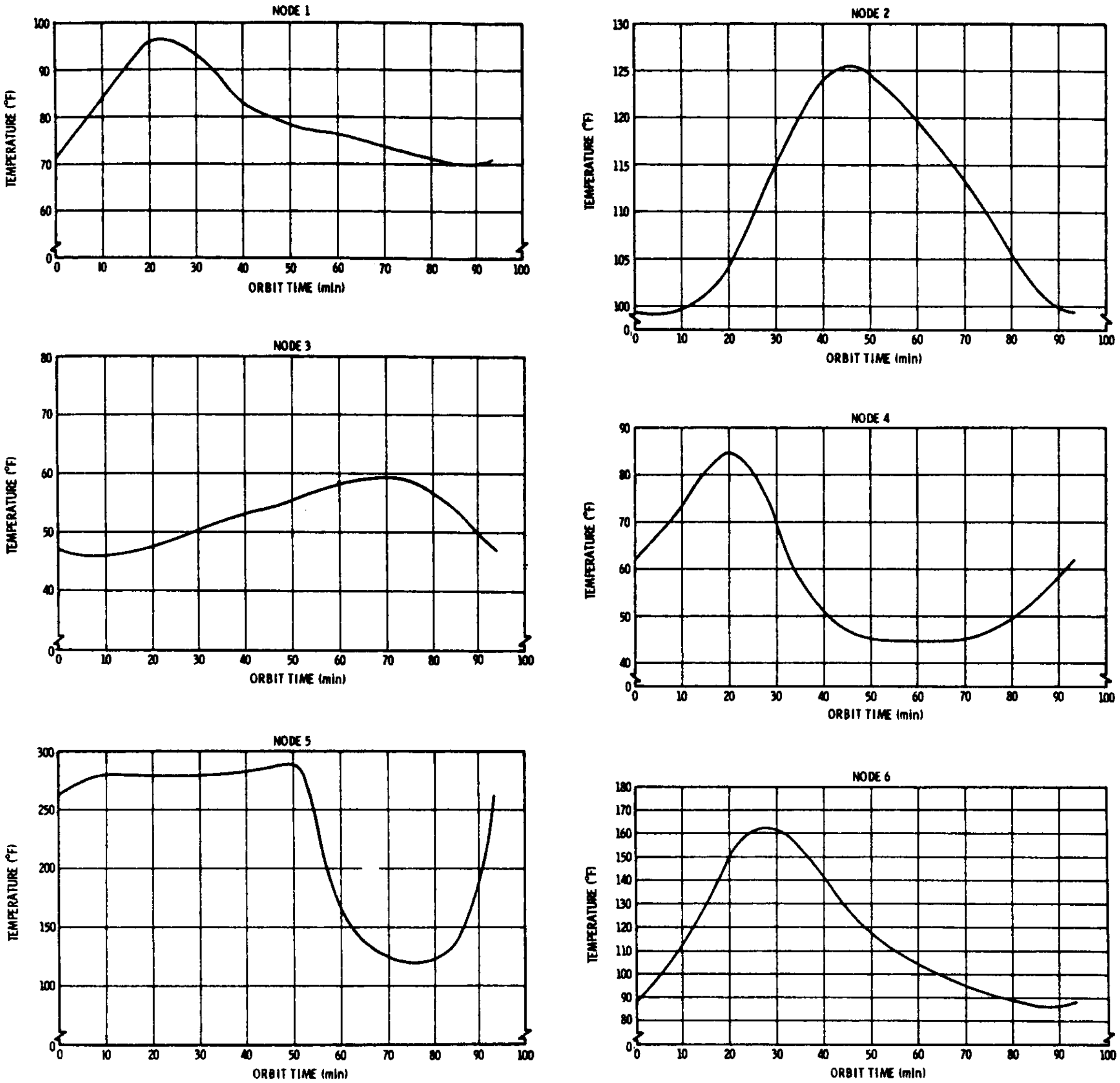


FIGURE A-28. COVER TEMPERATURES, PETERSON GAMMA-RAY DETECTOR, VERSUS ORBITAL TIME

TABLE A-5. EXPERIMENT BULK TEMPERATURES FOR THE OPERATIONAL MODE IN ATM-B CONFIGURATION I

Experiment	Operating Temperatures			
	T_{BULK} Average (°F)	T_{BULK} Maximum (°F)	T_{BULK} Minimum (°F)	Temperature Operating Limits (°F)
UV Photographic Survey (Tifft)	85	82	86	-4 to 104
Far UV Spectrograph (Carruthers)	8	12	4	-4 to 104
Modulated Collimator (Gursky)	5	5	4	-4 to 122
Gamma-ray Sky Survey (Frost)	72	73	70	-4 to 95
Digitized Spark Chamber (Fichtel)	62	66	59	41 to 104
X-ray Detector (Peterson)	86	93	83	-22 to 140
Gamma-ray Detector (Peterson)	127	138	117	-22 to 140
X-ray Sky Survey Panels (Friedman)	-12	-26	-23	-0.4 to 140
Far Ultraviolet Spectrograph (Morton)	28	39	22	±77

Friedman X-ray Sky Survey Panels, however, receive very little solar radiation due to shading by the ATM-A rack structure and solar panels. This caused the shell and bulk temperatures to drop well below the minimum operating limit. A heating apparatus, using part of the 300 watts reserved for thermal control, must be added to the X-ray panels. This apparatus should have the capability of keeping the X-ray Sky Survey Panels (Friedman) above -0.4°F at all times.

G. Control Panel and Display

The control and display subsystem design shall provide one or two astronauts with the capability to control and monitor the ATM-B experiments, the pointing control subsystem, the power subsystem, and housekeeping. The panel controls for these major functions shall be divided into hardwire commands and binary-coded commands. The panel controls shall provide hardwire commands and binary-coded commands. The hardwire commands shall be assigned, where crew safety items are involved, to frequently executed commands (once per orbit or more often), for short-time interval functions or where analog signals are required. The binary-coded commands shall be used for all other commands. Both techniques are used for some commands.

The control and display panel and TV monitors shall be designed for installation into the LM Ascent Stage crew cabin.

The control and display panel and TV monitors shall be designed for installation into the LM Ascent Stage crew cabin.

To conserve panel space all displays and controls shall be time-shared between systems when possible. All commands not hardwired will be originated by the application of a digital keyboard which generates binary-coded commands.

1. <u>Configuration</u>. The control and display panel shall be located in the LM forward center and left-hand tunnel area. The required panel area is approximately 1 700 square inches. The panel construction conforms with LM approach and concepts with regard to selection of instruments, module design, control and display hardware. The design makes maximum use of Apollo-qualified hardware.

2. Experiments Control and Display. The experiments controls shall share the keyboard used by the EPCS. The controls and displays shall be as required by the individual experiments under electrical design and performance criteria. As defined, the controls consist of individual switches and/or push buttons; the indicators are lights or meters; the displays are counters and/or cathode-ray tubes for TV display and housekeeping channels for that data which are monitored or telemetered. One 6-inch TV display with 1.2 seconds of arc resolution shall be provided on the control panel for monitoring the experiments which are mounted on the ultraviolet platform. The cameras are used for target selection and aiming.

3. EPCS Control. The EPCS controls and display shall be designed to meet specified coarse and fine pointing requirements dictated by specified experiments.

4. Power Control. The electrical power subsystem control shall provide control of the individual power modules (batteries, regulators, and chargers). Status monitoring or power module temperature, voltage, and current shall be on a time-shared basis between batteries. Provisions shall be made for automatic malfunction detection of any power modules. Solar panel deployment shall be controlled from the control panel.

5. Command Signals. Provisions shall be made in the ATM-B panel controls to send command signals to various control sources mounted on the rack. These signals shall be classified as follows.

a. Binary-Coded Command Signals. The binary-coded command signals drive a switch selector on the rack which provides a pulse output signal to a control distributor. A system utilizing three switch selectors can provide 336 discrete outputs with only 26 input wires. The switch selectors interface with the command decoder of the RF command subsystem to provide remote checkout and control.

b. Hardwire Manual Command Signals. The manual command signals shall be limited to the following types:

- Frequently executed commands
- Commands that cannot be given by coded methods because the time required to give the command is less than a minute

- Commands that control crew safety items
- Commands that switch ATM-B control panel meter readings
- Commands that involve the crew as part of the control loop.

6. Measurements. Besides TV display, the ATM-B panel design shall include provisions for bilevel and analog measurements.

7. Checkout. The ATM-B panel design shall provide capability for the command functions which can be accomplished by an RF Command Link. This will allow remote operation of the command output device to serve as the backup mode of operation.

8. Design Criteria. The design and display of control panel for ATM-B shall be in conformance with established guidelines for ATM-A, specified mission requirements, and guidelines specified in Paragraph D and G of this Appendix.

In addition to the above, the following items should be considered in the design:

- Minimize the number of wires connecting the rack to the ATM-B control panel in the LM Ascent Stage
- Minimize the wire size between the rack and the ATM-B control panel
- Minimize the ATM-B control panel's physical size
- Provide checkout capability
- Provide maximum design flexibility when interfacing with the experiments
- Maximum use of flight proven hardware
- Eliminate possibility of system power loss due to single point failure.

H. Maintainability

1. Maintainability Definition. The term maintainability pertains to quality of the combined features of equipment design and installation which facilitates the accomplishment of inspection, test, checkout, servicing, calibration, repair, replacement, and resupply with a minimum time, skill, and resource in the specified maintenance environments. The maintainability of equipment may be considered as a measure of the ease with which the equipment can be kept in operating condition. Sound factors of maintainability must be incorporated in the design of the ATM-B subsystems and components in accordance with corresponding sections of References 15 and 16. ATM-B maintainability should be based on cooperative effort of responsible engineering and human factors groups to ensure, within man's capability limits and other constraints, safe performance and good efficiency.

2. Types of Maintenance. Design for maintainability shall consider all of the following five types of maintenance to be used on the equipment:

(1) Regularly scheduled and unscheduled preventive maintenance tasks

(2) Testing

(3) Troubleshooting

(4) Replacement or repair of components and subsystem units

(5) Resupply.

3. Maintenance Criteria

a. Design for Ease of Maintenance. The design of ATM-B equipment shall include features to achieve maintenance objectives outlined in Paragraph 1. All maintenance criteria shall be analyzed and evaluated in the early stage of planning and design according to corresponding sections of Reference 15.

b. Reliability of Components. The design shall include the selection of components of high reliability to reduce and if possible to eliminate maintenance function without effect on performance.

c. Removal and Replacement. The subsystem equipment or components shall be replaceable at designated levels without disturbing or damaging other subsystems or components.

d. Safety During Repair, Replacement, and/or Resupply. During operations requiring repair, removal, replacement or resupply, service area shall be isolated and deenergized for astronaut's safety. Design shall include safety features such as guide rails, guide pins, limit stops, etc. for equipment removal/replacement. Attachment points at predetermined points shall be provided for astronaut to perform efficiently and safely various tasks under the EVA. Adequate lighting, identifiable labeling with due consideration on location shall be incorporated in the design in accordance with applicable sections of Reference 15.

e. Retest After Replacement. Replacements shall be tested to assure proper installation and operation.

f. Special Tools. Special tools shall be identified and provided where necessary.

g. Modular Design Considerations. Factory type maintenance requirements shall be minimized through the application of modular design concept.

h. Manual Switching. Wherever possible requirements for EVA manual switching shall be minimized and consolidated at EVA film replacement retrieval.

i. System Analysis Tradeoffs. System analysis tradeoffs shall be conducted considering such factors as weight, power, automatic or manual operation, complexity, etc.

j. Service Timing and Power Expenditure. When maintenance action is taken, the ATM-B subsystem, equipment, or component shall be serviced in a given period of time, with a given power expenditure to assure satisfactory operating condition for a specified duration.

4. Specific Maintainability Criteria

a. Unitization. Concept of unitization of the equipment shall be improvised in the design wherever feasible for rapid and easy removal or replacement of malfunctioning units in accordance with corresponding sections of Reference 15.

b. Location of Components. In design determined location of components, units shall be according to specified sections of Reference 15 with attention given to size, weight, arrangement, available space, testing, parameters, etc.

c. Mounting of Units. Design of mountings of various units shall be in accordance with pertinent requirements specified in Reference 15. Consideration shall be given to code interchangeable units, arrangement, frequency, unit removal, equipment extensions, standard orientation, location of instruments, etc.

d. Operating Conditions. Men and equipment are affected by their surrounding environment. The designer shall assume the extremes of the possible environmental conditions under which the equipment must be maintained. He shall provide features to facilitate maintenance under such conditions.

5. ATM-B Film Replacement/Retrieval Guidelines. The ATM-B film replacement/retrieval guidelines are as follows:

- Astronaut extravehicular activities (EVA) shall be conducted from the Airlock Module (AM) according to specified plan using an A6L Block II Apollo pressure suit and an umbilical as the primary mode of operation.

- The Portable Life Support System (PLSS) shall be used only as a backup mode of operation.

- Translation during EVA shall be by use of handrails placed over the structure.

- Removal and replacements of film cassettes shall be under reduced gravity, one-hand operation and based on estimated maximum frequency of 4 to 6 days during a 56-day mission. Estimated time for each EVA task in performing Gursky experiment is 4 to 10 hours total in periods of 15 to 30 minutes. Means for safe return of films to Earth must be provided.

- Platforms shall be moved back closely to the rack to facilitate the film retrieval.

- EVA of astronauts shall be continuously monitored.

- Film cassettes shall be color coded and tethered during replacement operations.

- Weight, size of loaded film cassettes (experiments by Tifft, Carruthers, Morton and Frye) shall be according to astronaut capabilities and other specified requirements.

6. Accessibility/Retrieval of Film Cassettes. Accessibility/ retrieval of film cassettes should be considered from the standpoints of:

- Accessibility to work area

- Accessibility to experiment

- Retrieval method

- Visibility

- Reflection of Sun from equipment and effects on optics

- Tether operation

- Experiment doors

- Umbilical length (58-foot maximum)

- Astronaut suit constraints

- Astronaut physical capabilities

- Safety monitor using external viewing aids

- Required clearance for astronaut's movement around equipment under defined stabilized conditions of flight.

I. Reliability and Quality Assurance

Reliability and Quality Assurance Program for the ATM-B system shall be in conformance with the ATM-B Quality and Reliability Assurance Plan MSFC (to be issued), References 17 through 19 and incorporated information from Paragraph H of this Appendix. The program shall be supported by corresponding sections of References 20 through 24 and Military and other Government Specifications, Standards, and Procedures. The reliability and quality shall not be degraded through procurement, manufacturing, assembly, transit, test, and use. The accomplishment of these objectives shall be achieved by meeting the following requirements:

(1) Planning, scheduling, and efficient management of Reliability and Quality Assurance Program which is an integral part of design, development, manufacturing, assembly, test, checkout, inspection, correction, and retest processes.

(2) Continuous indication and control of the reliability and quality assurance effort in conformance with specified system of documentation, reports, government inspections, and reviews.

(3) Design of ATM-B subsystems, equipment, and components according to specified safety margins, derating factors and apportioned reliability goals to meet established environmental and pertinent test performance criteria to conform with specified mission profile requirements.

(4) Continuous and efficient effort in the early conceptual design stage to institute development of reliability prediction models for subsystems, equipment, and components. These models shall be revised as required by evaluation of the subsystem design and changes. As data from specific reliability engineering analyses and various test results become available, this approach shall be used as:

- A timely means emphasizing potential reliability problem area and guiding design trade-offs

- A basis for required test program planning, reliability assessment, and evaluation program

- A guide for required additional failure mode, effect, and criticality analyses and flight assurance tests

- A basis for study and determination of specified redundancy at subsystem and component level.

(5) Continuous relationship with designated human engineering groups to improve design, maintain safety margins, and assure compatibility with astronaut's capabilities and limitations. This is based on developed prediction models which include evaluations of early designs and performance characteristics.

(6) Reliability and Quality Assurance Program shall include analyses for redundancy of subsystems, components to assure astronaut safety, and mission operations. Necessary recommendations shall be made to correct, design, assure specified automatic, semi-automatic, manual operational modes, or combinations thereof for emergency purposes and intent to achieve mission objectives.

(7) Provision and maintaining of effective standards for elimination of potential sources of human induced errors, failures throughout the entire effort from basic design through operational use.

(8) The reliability of the ATM-B shall meet established overall reliability system goals based on definition of mission requirements.

• 56-day LM/ATM-B orbital operations	0.75
• Orbital storage and reactivation up to 135 days	TBD
• Crew safety	0.995

(9) The reliability and quality assurance program shall also include failure mode, effects and criticality analysis according to NASA approved Standards and Specifications. The Reliability and Quality Assurance Program shall include the analyses of the following listed subsystems:

(a) Mechanical subsystems

- Solar panel deployment and retraction mechanism
- Control-moment gyros
- Experiment Pointing Control Subsystems (EPCS)
  - ▲ CMG inverter assemblies
  - ▲ Sun sensor assemblies
  - ▲ Star tracker assemblies
  - ▲ Rate gyros
  - ▲ Actuators: roll, pitch, and yaw
  - ▲ Control computer assemblies
- Experiment platforms and associated deployment mechanisms
- LM interface and guillotine cutoff mechanism
- Experiments (See Paragraph A of this Appendix)

(b) Structural subsystems

- Rack assembly
- LM interface
- Control panel (in LM)

- Solar panel structure and mounting
- Experiment housings, mounting and environmental shells
- Experiment platforms and mounting
- Film cassettes (including protective shielding)

(c) Electrical subsystems

- Control panel and display
- Experiment control (operational, thermal, etc.)
- Power supply
  - ▲ Batteries
  - ▲ Solar panels
  - ▲ Battery charging/power regulation
  - ▲ Power distribution
- Instrumentation and communications
  - ▲ Measuring
  - ▲ Telemetry
  - ▲ Command
  - ▲ Antenna
  - ▲ Television

J. Tests

The overall test program for ATM-B must yield maximum confidence that the hardware will operate as required in the prescribed environment through the mission duration.

The test program shall cover all testing required for the ATM-B project including design evaluation, manufacturing processes, qualification, acceptance and prelaunch activities, personnel training and documentation. The test plan shall also establish the general requirements for preparation of detailed test documentation. The following guidelines should be utilized in developing the ATM-B test program:

- The several phases of the test program, consisting of development, qualification, acceptance, integration, and reliability testing, shall be closely interwoven to make maximum utilization of test hardware and provide results within the shortest time frame.

- All tests shall be performed at the highest hardware generation level practical with minimum piece part testing.

- Acceptance tests shall be conducted at the origin of manufacture when practical to reduce duplicate testing and resources at the integration and/or assembly site.

- Existing resources and those scheduled for ATM-A shall be utilized where practical (facilities, equipment, procedures, data, and personnel).

- Results of the ATM-A program shall be utilized where possible and only the difference between the programs would be tested.

- Requalification shall be avoided.

- Qualification shall be accomplished by analysis or similarity analysis where practical and supplemented with testing when the analysis is not considered adequate for qualification.

- Qualification test hardware shall not normally be utilized as flight or backup equipment. In the event such hardware must be utilized, it is essential that crew safety is not compromised and the hardware is recertified by replacing those components whose performance may have been degraded by environmental testing.

- Materials compatibility testing shall be conducted, where adequate data is not available, to certify that the material selected is compatible over the specification range with both fluids and other interfacing materials under the expected use conditions (e.g., manufacturing, testing and extended flight exposure to the space environment).

- Subsystems which are not required to operate until after orbit is achieved shall not normally be functionally tested during tests simulating the ignition through orbit phase, but shall be functionally tested before and after such simulated testing to insure proper operation without degradation or damage.

1. Development Testing. Development testing shall include tests required to evaluate and optimize the ATM-B design and shall be performed to establish a configuration complying with mission requirements.

Ultimate objectives shall be to identify design weaknesses and to identify areas of performance degradation to permit early optimization of design. Evaluations on hardware performance under simulated or actual environmental conditions shall be conducted. Tests shall include engineering evaluation of components and subsystems, systems compatibility, and the total system.

Development tests shall be concerned with areas where present qualification data are unavailable, or inadequate, and additional information regarding various materials and processes is necessary to proceed with a design. Modifications and repairs resulting from testing failures shall be documented and incorporated as design changes.

Development testing shall encompass static structure, vibration, thermal-vacuum, temperature, shock, acceleration, RFI, and EMI.

Prototype rack structures shall be used for the system level development tests. One prototype (structural unit) shall be utilized for static structural and developmental thermal testing. Another prototype (vibration unit) shall be subjected to developmental dynamic testing.

a. Structural Unit. The structural unit shall be instrumented and tested to determine structural integrity under maximum flight loading conditions. When the static tests are completed, the structural unit shall be equipped with dummy thermal components which shall simulate the thermal characteristics of the flight hardware. The structural unit when equipped with the dummy thermal components shall become the thermal unit.

b. Thermal Unit. The thermal unit shall be tested in a thermal-vacuum and the test results utilized for early developmental studies to determine the thermal parameters associated with the system and gain confidence early in the developmental program that thermal control techniques are adequate.

c. Vibration Unit. The vibration unit shall be equipped with dummy components which simulate size, mounting provisions, mass, and center of gravity of flight hardware. The unit and LM structure simulator shall be subjected to sinusoidal and random vibrations and acoustic pressure. Test results shall be utilized to verify design and adequacy of qualification test levels.

2. Qualification Testing. Qualification testing will demonstrate the capability of hardware, not previously qualified, to meet the established design criteria. Tests shall be designed to provide a high level of confidence that all items of hardware will survive the environment they will encounter and perform the specified mission successfully. Test articles used for qualification shall be flight configuration and they shall be manufactured by the same method and to the same tolerances as the flight hardware. Final qualification testing of the components and systems will occur during testing of the integrated ATM-B.

Qualification testing will be designed to locate significant failure modes and determine stress levels imposed under varying combinations and sequences of events and environments. The objective of the qualification testing shall include:

- Determination of the structural and dynamic characteristics of the hardware

- Determination of functional characteristics under conditions simulating operation

- Determination of compatibility of equipment.

3. Flight Prototype Testing. Flight prototype testing will include testing objectives, in addition to those specified for components and subsystems:

- Verification of form and fit of the various subsystems and components

- Verification that the integrated system will perform within design limits when subjected to the environments it will encounter.

4. Acceptance Testing. Acceptance testing shall be an integral part of production activities. The test program shall confirm that manufactured operations have been accomplished in accordance with engineering documentation; that the tested items have met all design criteria and intent; and that tested items interface physically and functionally with other flight and ground support equipment items.

Acceptance testing shall normally be conducted at the manufacturing site, although acceptance testing will be conducted until vehicle launch. Test articles for qualification testing will be subjected to specific acceptance tests.

5. Integrated Systems Testing. The integrated systems testing of the ATM-B shall be of the "building block" concept and shall be divided into the following major areas.

a. Power Distribution Tests. The power distribution tests shall be the initial functional test conducted on the ATM-B undergoing checkout at any location. Successful completion of these tests shall assure the compatibility of the flight article and ground support equipment, correct assembly, proper power distribution, correct design and readiness of the power subsystems for succeeding tests.

b. Subsystem Tests. Tests shall be performed upon each subsystem and experiment to insure that each performs in a manner that shall verify the established test requirements and specifications. Redundant systems shall be tested to insure the operability of each system independent of its redundant system.

c. Simulated Mission Tests. The simulated mission tests shall consist of an all-systems verification with operational functions programmed to simulate mission requirements.

d. The Electromagnetic Compatibility (EMC) Tests. The EMC tests shall verify (1) operational "safety margins" of conducted transient interference, (2) that no electrical-electronics subsystems are adversely affected when the ATM-B is subjected to a simulated prelaunch, launch, and flight sequence, and (3) that radio frequency (RF) transmission parameters are within tolerances. A radiated spectrum surveillance of the payload and associated equipment shall be performed and compared with the launch vehicle frequency spectrum to assure intra-system compatibility.

It would be best to perform the simulated mission tests and the electromagnetic compatibility tests with a prototype LM ascent stage provided the latter can be made available to MSFC.

6. Operational Vibration Testing. The ATM-B and its ground support equipment (GSE) shall be transported to a vibration facility upon completion of the system acceptance tests. ATM-B systems that are to have power applied during the actual launch phase will have power applied during the vibration testing. Following the application of specified vibration levels, a systems test shall be performed on the ATM-B.

7. Thermal-Vacuum Testing. The integrated ATM-B shall be placed in a thermal-vacuum chamber and simulated mission test performed at specified thermal and vacuum levels.

8. Prelaunch Testing. Since the GSE shall generally be shipped with the integrated ATM, the utilization of common test procedures for systems acceptance tests and prelaunch tests should be possible.

9. Test Schedule and Hardware. Test schedule and hardware shall be prepared which is compatible with ATM-B Project Milestones.

10. <u>Environmental Test Criteria.</u> The test levels and procedures for ATM-B system environmental requirements shall be as specified for ATM-A. The net results of these tests shall verify proper equipment sequencing, control capabilities, and equipment operational compatibility (Ref. 25, 26, and 27).

K. Ground Support Equipment

1. <u>Vehicle Checkout.</u>

a. Launch Vehicle GSE. A configuration utilizing a Saturn IB with an S-IVB stage is the launch vehicle for the proposed payload for ATM-B. Since this vehicle is standard flight hardware, it will utilize existing checkout procedures and equipment, including the RCA 110A computer system.

The launch vehicle and ATM-B checkout systems should be independent because of the limited payload repeatability.

b. Lunar Module GSE. Present functional and prelaunch tests performed on the complete LM system utilize fluid, mechanical, and electrical ground support equipment classified as Acceptance Checkout Equipment - Spacecraft (ACE-S/C). This system may be used in an automatic, semiautomatic, or manually-controlled mode and its capabilities include the generation of test commands and stimuli, monitoring of spacecraft subsystem performance, conversion and processing of data, measurement of subsystem responses to test stimuli, diagnostic testing, and communication between the LM and ACE-S/C control (see Ref. 28).

With the same basic configuration of the LM section for all ATM missions, the LM checkout equipment and procedures could be standardized except for the experiment-oriented systems.

Since the ACE-S/C system is based on a building block approach, some integrated system checkouts involving the experiments could be carried out with certain interface changes to the system. However, because this would require one-time changes to a basically established system it will be assumed that the most efficient approach would be through the use of separate experiment-oriented checkout equipment.

Experiment Checkout Equipment (ECE), Electrical Support Equipment (ESE), Ground Equipment Test Sets (GETS), and Mechanical Support Equipment (MSE) peculiar to the ATM system could be utilized for the portion of the LM checkout associated with the experiments.

There will be a requirement for an LM simulator during any LM/ATM integrated system checkout prior to delivery to KSC.

There will also be a requirement for an ATM simulator for use with the LM at MSC for astronaut training.

2. Experiments.

a. Experiments and ECE. The cognizant Principal Investigators will furnish the experiment hardware and related ECE. The ECE will be portable "carry-on" or "carry-near" equipment to provide the stimuli or input to the experiment package for checkout or calibration of the experiment. Since each set of ECE will be unique, there will be a requirement for new cabling or umbilical connections for all ATM-B experiments.

It is presumed that each experimenter will be responsible for special test equipment which may be required during the experiment development program and for acceptance tests by Government source inspection personnel.

Experiment simulators may be required for operational training if prototypes or working models are not available.

b. Deployment Mechanisms. New checkout equipment will be required for the deployment mechanisms associated with the experiments.

c. Ultraviolet Photographic Survey. This experiment should not require any major modifications to the support equipment available from ATM-A. Basic changes would be associated with the functional checkouts and handling or alignment fixtures. The necessity for a gas atmosphere to prevent excessive drying of the film stored in flight would be considered for possible support requirements.

d. Far Ultraviolet Spectrographs. The most stringent changes to support equipment related to these experiments will involve the water vapor contamination problem, especially for the Carruther's unit. This may require a separate enclosure for the experiments to provide a dry nitrogen purge until orbit is achieved. Some modifications to existing equipment will be required for the functional checkouts and handling or alignment fixtures.

e. Modulated Collimator X-ray. Except for the functional checkout and handling and alignment fixtures, there should be no major changes required to the ATM-A GSE for this experiment.

f. Low-energy Gamma-ray Sky Survey. This experiment should not require any major GSE changes outside the area of functional checkout and handling and alignment fixtures.

g. Spark Chambers. In addition to equipment changes to perform the functional checkout and new handling fixtures, this experiment will utilize a pressurized enclosure which would require supporting ground equipment.

h. Medium-energy Gamma-ray Spectrometer. No GSE changes should be necessary for this experiment except for checkout functions and handling fixtures.

i. X-ray Panels. The additional ground support equipment for this experiment will relate primarily to the requirement for a P-10 (90% Argon -10% Methane) gas supply for the counters.

If it is necessary to maintain this gas atmosphere at all times on the counters, there will be a requirement for a supply to be incorporated as part of the environmental control peripheral equipment. Otherwise, a supply will only be required during operational checkout.

The MSE at KSC will require the capability to fill the high pressure bottles on the ATM-B with P-10 prior to launch.

3. Structure. The structural assembly tooling used for ATM-A should in most instances be reusable on ATM-B with minor modifications. Such items as the upper and lower ring assembly fixtures, the structural assembly fixture and the LM ascent stage adapter should not require

modifications. Work platforms will probably require changes, with additional support equipment being required for the deployment mechanisms and platform assembly.

The ATM-B rack will require testing to determine its structural integrity under maximum flight loads. Available facilities would be utilized for the static and dynamic tests required on the rack, and most of the test fixtures from ATM-A could be reused.

4. <u>Support Systems.</u>

a. Instrumentation and Communications. Because of the standard nature of this type hardware, there should be no requirements for specially developed ground support equipment to qualify the component parts used in the instrumentation or communications subsystems. The checkout of these subsystems is discussed in the area of Data Management.

b. Power Supply and Networks. The use of a power supply system similar to ATM-A with solar cells, batteries, battery chargers and regulators is assumed for this payload. This would allow use of basically the same supplementary power supplies and power supply checkout equipment. The use of fuel cells or other power sources could require extensive changes to the supporting equipment or development of a completely new set of equipment.

The test sets which have been developed for checkout of the power distribution system and interface connections on ATM-A would require minor modifications for the ATM-B configuration.

The test equipment already developed for qualifying the power system components, such as the solar cells, could be reused. Any new methods for solar cell deployment may require modifications to the existing ATM-A checkout equipment, including the zero-g simulator system.

c. Pointing Control. The use of an ATM-A type Control Moment Gyro (CMG) system for coarse pointing control will allow use of the available support equipment. Deletion of the gimbal system for fine pointing control will simplify the support equipment requirements in this area. Since the ultraviolet experiments utilize a gyro stabilized platform (provided by MSFC), there will be a requirement for new support equipment such as checkout fixtures and control panels for this system.

d. Environmental Control. The thermal control requirements of ATM-B should be basically passive or semiactive using heater elements which would require a minimum of support equipment other than test facilities.

The available ATM-A checkout equipment and test facilities required for rack structure thermal tests should be applicable to ATM-B with minor alterations.

Other environmental control systems associated with ground checkout and prelaunch activities would be basically the same for ATM-A or B. This would include the environmental control equipment for the transporting container, the SLA purge equipment, and the available clean room facilities. Three clean rooms will probably be available from the ATM-A program. These will provide a contaminant-free environment with temperature and humidity controls for system assembly, checkout and operation.

e. LM Control and Display Units. The development of LM control and display units for astronaut use will be a combined effort between the Principal Investigators and MSFC. The support equipment basic to this area will be the necessary ESE which performs command and monitor functions from a remote location. (This equipment is discussed in the Data Management section). Although a major modification will be required in the functions of the ESE, the basic hardware from ATM-A could probably be utilized for the new system.

5. <u>System Test and Checkout.</u>

a. Assembly. The final assembly of the experiments and subsystems on the ATM rack structure will require the modification of existing equipment and probably will require some new assembly fixtures. The major items such as the final assembly and optical alignment fixtures and the tooling ring should be reusable with modifications.

b. Optical Alignment. Except for the required changes previously noted in the alignment fixtures, the optical alignment equipment available from the ATM-A program should be satisfactory for use on ATM-B. The same "zero-g" optical alignment concept using springs or counterweights can be used with appropriate modifications for the experiment changes.

c. Test and Checkout. The primary modifications to the ESE, MSE, GETS and optical verification equipment will be a result of experiment changes. Other than this, the same facilities and equipment used for ATM-A test and checkout should be suitable for ATM-B checkout.

6. Transportation and Handling. The transporters, enclosures, pallets, slings, and tiedowns used on ATM-A should be reusable with minor modifications. Attach points, interfaces and the instrumentation system will affect the interchangeability.

The peripheral environmental control equipment should be reusable with the incorporation of additional capability as required by the experiments. Any spare parts, additional components, and the GSE which will accompany the ATM-B will require transportation provisions.

7. Launch Preparation. The changes to the support equipment for use at the launch site should be minor. The checkout equipment will have to function within the normal prelaunch constraints. The work platforms used on ATM-A should not require major modification. The SLA and nosecone handling equipment would be the same, as would the power supply units and nitrogen purge equipment. The major modifications would involve the equipment for special environmental control, and the equipment for fill and drain of expendables required by the experiments.

8. Flight Support. Unless a special ground simulation model is to be used during the flight for assistance in correcting malfunctions, no requirements would be considered for GSE during the flight mission.

The Manned Space Flight Network (MSFN) facilities would presumably have the necessary facilities for accumulating and formatting the data for distribution to the Principal Investigators for reduction, evaluation and publication (Ref. 29 and 30).

L. Human Factors

The cooperative effort of the Human Engineering personnel shall extend to the entire ATM-B system design, development, manufacturing, handling, testing, reliability, operation, and maintainability to ensure the efficient integration of man's capabilities and limitations in the specified mission program. Principles, methods, and procedures of Human Factors Engineering shall be applied to the above areas of effort in accordance with References 15, 16, 21, 32, and 33, and other NASA approved specifications. The role of Human Engineering is to increase and preserve the effectiveness of man in the planned mission program within the parameters established by the system requirements. The close cooperative effort of the Human Factors personnel with assigned ATM-B engineering groups is also for the purpose of increasing and ensuring compatibility of ATM-B equipment with the man, reliability, safety, and to achieve successful and efficient mission objectives. A complete record of required action analyses, by Human Factors Engineering personnel in various areas and phases of the ATM-B program, shall be maintained for reference, elimination of human error, and promotion of the effective and harmonious progress in the program. Required Human Factors Engineering personnel participation and responsibilities are detailed in the following paragraphs.

1. Design and Development Support. Human factors specialists shall take an active part in the design and development effort of the ATM-B configuration. During the design phase, the human factors engineering inputs made in accordance with the system analysis requirements, as well as other appropriate inputs, shall be incorporated into the design features of the system by the cognizant technical activity. A file shall be established on each identified end-item having a man/machine interface. This file shall contain all the human engineering evaluations, considerations, and study results produced by the group. The file shall be made available to design and other authorized groups.

a. Equipment Layout. Human factors criteria and recommendations developed during system analysis shall be applied to system and subsystem preliminary layouts and related drawings. The approval of layout drawings by the human factors engineering group shall verify that the configuration and arrangement of equipment satisfy man/equipment performance requirements, and that the design complies with applicable and approved human factors standard specifications.

b. Equipment Design. Human factors principles and procedures shall be applied, during detail design, to equipment drawings involving panel layouts, workspace, access areas, communications systems, controls, and other drawings depicting equipment necessary for system operation and maintenance by human operators. Concurrent with the review of design drawings, all available written documentation shall be reviewed for omission, ambiguity, consistency, and completeness to ensure that potential human error situations are minimized or eliminated.

c. Crew Station Layout. The requirements and criteria for workspace layout shall be identified in detail considering the following:

- Tasks to be accomplished
- Safety in normal and emergency situations
- Man capabilities and constraints
- Suit limitations
- Equipment to be used
- Sequence and frequency of activities
- Anthropometry
- Crew number
- Access
- Safe and timely traffic flow patterns
- Unobstructed movement
- Visual links between operations
- Adequacy of illumination
- Labeling coding
- Arrangement of equipment, controls, etc.

d. Environment and Life Support. Life support for astronaut's survival, protection, comfort, and endurance against all environmental effects including those of closed ecology (man-microbiol symbiosis), biochemical, and taxicological shall be in accordance with specified mission requirements. The life support system should be capable of withstanding specified environmental effects due to atmosphere, temperature, humidity, radiation, acceleration, vibration, noise, gravity, and orientation. Comfort factors shall be included to the extent of assuring astronaut's maximum performance under adverse conditions.

e. Design Review. Human factors engineering personnel shall participate in all design reviews to ensure consideration of (1) personnel operations and personnel/equipment interactions and (2) control in areas of maintainability and reliability and quality assurance.

2. System Analysis. Human factors personnel shall participate in system analysis throughout system design and development. Required system functions shall be assigned to man and equipment in a manner to ensure maximum system reliability, efficiency, and safety. All astronaut activities shall be analyzed to identify activities requiring interaction with equipment and other personnel.

a. Personnel Activities Analysis. A detailed time-phased profile shall be constructed for all astronaut operations and maintenance activities. Time and flow of operations shall be analyzed to assure comprehensive identification of activities, proper phasing, avoidance of human overload, and detection of all human and equipment interfaces. Relevant information identifying these activities shall be selected and correlated with each function in the system analysis. This information shall be updated continuously to reflect changes during design/development of the system.

b. Task Analysis. Tasks involving critical human performance shall be further defined to the necessary level of detail through a task analysis. Also, personnel activities applied to equipment or components defined as system critical shall be subject to task analysis. This information will be used as a basis for making design recommendations and also serve as basic information for development of procedures. The identification of human outputs shall include physical location, performance time limits, reliability, and support requirements.

3. Testing and Evaluation. To meet the requirements of this program, a testing effort shall be instituted to evaluate the adequacy of the human engineering considerations and provision in the design of the system. This testing shall be initiated during the earliest possible portion of the development cycle so that changes can be made at a minimum cost.

a. Static Evaluations. When required, models and mockups shall be fabricated to study design concepts and human reliability problems. These mockups shall be used in tests designed to determine the adequacy of workspace layout, operability, maintainability, and safety of equipment including its associated facility environment. Full scale mockups shall be prepared only when existing mockups do not meet the requirements of the programmed analysis. Design verification tests shall be made on the first full scale hardware before operational use to identify human engineering deficiencies that were not evident in the drawings or mockups. These tests shall be evaluated utilizing a checklist based on Reference 15 and any additional operability or maintainability ground rules peculiar to the system. Departures from the above criteria shall be documented and their impact upon the system shall be evaluated.

b. Dynamic Evaluation. Human factors engineering shall participate in the dynamic system test program at all test sites and at the operational location. Critical human performance areas shall be observed as often as necessary to ensure maximum human reliability. The human factors engineering personnel shall support the validation and verification of man interfaced equipment, maintainability, and reliability and quality assurance. Recommendations for corrective action as a result of the test shall be made to the appropriate group as promptly as possible.

4. Crew Training. A crew training program shall be conducted to ensure safe, timely, and efficient performance of the crew members during specified missions.

5. General Scope of the EVA. General scope of astronaut participation in the performance of ATM-B experiments is described in Paragraph A of this Appendix. Some modifications are anticipated in these experiments which may affect the extent of the EVA. All necessary corrections in the EVA analysis must be made accordingly until all modifications are completed and approved by NASA.

6. General Requirements. Effort shall be made to eliminate or minimize the level of the EVA wherever feasible and practical.

a. Automation. Functions shall be automated when the following conditions exist:

- Astronaut cannot perform within required range of precision, sensitivity, reliability, time, sequence, risk, and flexibility.
- Astronaut becomes overburdened with functions/tasks related to operations, maintainability, and film magazine retrieval/replacement. For example, the EVA could be eliminated by having an automated film retrieval mechanism.

b. Controls and Displays. Controls and displays shall be selected with consideration of the following conditions:

- Available control panel space
- Defined task requirements for each astronaut
- Determined man/system functions and operational requirements
- Established power weight and space constraints
- "State-of-the-art" considerations and known characteristics of controls
- Operator's intellectual, physical and psychomotor capabilities
- Operator's perceptual skills (visual, auditory, tactual, kinesthetic).

The above stated functional and operational requirements shall be classified according to (1) information required by the astronaut to perform his function, (2) information required by the hardware system to perform its functions, and (3) time limits on all operations.

The controls and displays shall be designed and arranged according to specified guidelines:

- Mission priority
- Usage frequency
- Sequential dependencies
- Functional grouping with due consideration of human elements used efficiently in operating and maintaining the ATM-B equipment.

c. Safety. Consideration shall be given to safety factors, including minimization of potential human error (i.e., checklist, visual display, etc.) in the operation and maintenance of the system. Where adherence to the design practices results in degradation of the system safety, the safety consideration shall have priority. During EVA, equipment areas which require servicing must be isolated from power supply for astronaut's safety (i.e., experiment platform in time to remove or change a film).

d. Simplicity. The equipment shall be of the most simple design possible that will fulfill functional requirements, meet expected efficient service conditions, and permit maximum operation, maintenance, and repair by semi-skilled personnel. Film cassettes which must be removed and replaced shall be designed for one-hand operation.

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ERRATA AND CLARIFICATION SHEET
for
Summary Report SSL-29131-7

"PROPOSED PAYLOAD FOR ATM-B FOR OBSERVING HIGH-ENERGY CELESTIAL SOURCES"

January 15, 1968

- PAGE 42 LAST PARAGRAPH CLARIFICATION: In the January 15, 1968 report, the X-ray scan rate was assumed to be limited by the Gursky experiment to 2 deg/min. Scanning the portion of the celestial sphere which would be visible to the X-ray instruments during the mission would require 27 hours at 2 deg/min. This amount of scan time could be provided in 21 orbits.

  If the faster scan rate of 4 deg/min permitted by the Friedman experiment were used, the X-ray scan could be completed in 13.5 hours. This amount of instrument time could be provided in 10.5 orbits. Therefore, X-ray scan could be completed on Mission Day 10 rather than on Mission Day 11.

- PAGE 53 FIRST SENTENCE, LAST PARAGRAPH: Reword to read "This platform is also located on a telescopic boom which is orientable, but not stabilized"

- PAGE 89: The energy range of the Peterson Experiment is incorrect. It should be "Gamma Ray 0.3-10 MeV and X-ray 1-30 keV"

- PAGE 112, SECTION 2, LAST PARAGRAPH, FIRST SENTENCE: Delete "for the ASAP unit."

- PAGE 112, SECTION 2, LAST PARAGRAPH CLARIFICATION: Each Auxiliary Storage and Playback (ASAP) assembly contains a primary and a redundant or standby magnetic tape record-and-playback unit.

  Transmitter redundancy is provided by the switching network in Figure 22. Two transmitters are required for playback of data from the two ASAP assemblies. A third transmitter is provided for real-time telemetry. Should an ASAP transmitter fail during a playback, the switching network would "steal" the real-time telemetry transmitter for use by the ASAP until playback was completed. Conversely, during recording periods, an ASAP transmitter may be used for real-time telemetry data.

ERRATA AND CLARIFICATION SHEET
for Summary Report SSL-29131-7
Page 2

- PAGE 114, TABLE A-4: Change reference from Table 4 to Table 3.
- PAGE 116, SECOND LINE: Delete "for redundancy"
- PAGE 165: References 2 and 7 are identical.